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COMMERCIAL FRUIT AND VEGETABLE PRODUCTS

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COMMERCIAL FRUIT AND VEGETABLE PRODUCTS

COMMERCIAL FRUIT AND VEGETABLE PRODUCTS

A TEXTBOOK

FOR

STUDENT, INVESTIGATOR AND MANUFACTURER

BY

W. V. CRUESS

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FIRST EDITION

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PREFACE

This book has been prepared primarily to serve students in horticulture, food chemistry and horticultural products. Therefore the application of the fundamental sciences to the manufacturing and preserving processes concerned is given prominence equal to that of the strictly practical phases. The book is based upon lectures given by the author to students in fruit and vegetable products during the past ten years and the subject matter is developed from the viewpoint of the instructor rather than from that of the manufacturer.

Nevertheless, it is believed that commercial canners and others engaged in the fruit and vegetable products industries will find most of the information given upon their respective industries of direct value in the operation and control of their plants. In addition to serving as a reference book for the factory manager, superintendent, or chemist the book will be of value to the foremen and other employees in the organization who desire to increase their technical knowledge of the industry.

In conjunction with the Laboratory Manual of Fruit and Vegetable Products by Cruess and Christie, the present book may be used as a text for University and College courses in the subject. The list of references given at the end of each chapter may be used by the instructor in assigning outside reading or by chemists and others who may wish to consult original sources.

Fruit and vegetable products have long been important articles of commerce and for many centuries have formed a large proportion of the diet of man. Many of these products were first prepared in the household on a small scale before their commercial production was undertaken and others, since the beginning of their manufacture, have been prepared on a factory scale.

Some may be termed "primary products," since the fruit and vegetables used are grown principally for the manufacture of the products concerned. The canning of fruits and vegetables, the pickling of cucumbers and the manufacture of tomato catsup are primary industries. The manufacture of vinegar from waste fruits, of fixed oil from apricot kernels and raisin seeds and of charcoal from fruit pits or hulls are by-product industries, since only fruit waste is used.

Both primary products and by-products are important in relation to modern fruit and vegetable growing.

In order that this book may not cover too wide a field, attention will be centered principally upon those industries more directly affecting the fruit and vegetable grower rather than the producers of field crops and of livestock.

The intelligent application of scientific methods and principles in the fruit and vegetable products industries has been comparatively recent. Although notable advances have been made in the knowledge of the fundamental scientific principles underlying processes used in these industries, there remains to be done a vast amount of research before the manufacturing processes are placed upon the same high plane of efficiency and applied science as for example, obtains in the manufacture of beet sugar. The opportunities for investigation by chemists, physicists, bacteriologists and engineers in the fruit and vegetable products field are almost unlimited.

The author is deeply grateful to his associate, Professor A. W. Christie for his generous and painstaking work of proofreading and for many helpful suggestions and much useful information given during the preparation of the manuscript. The author also desires to acknowledge his appreciation for information and other assistance given by Dr. W. D. Bigelow and his associates of the National Canners Research Laboratory; Dr. B. J. Howard and Dr. H. C. Gore of the Bureau of Chemistry, U. S. Department of Agriculture; Dr. A. W. Bitting and Mrs. K. G. Bitting, formerly of the National Glass Container Association; Prof. F. T. Bioletti, Dr. K. F. Meyer and J. H. Irish of the University of California; Dr. E. C. Dickson of Stanford Medical School; U. S. Forest Products Laboratory at Madison, Wisconsin; G. B. Ridley, C. A. Magoon, C. W. Culpepper, J. S. Caldwell, A. H. Bryan, Dr. Th. von Fellenberg, C. P. Wilson, Dr. E. M. Chace, D. L. Quinn, *The Canning Age*, *The Canner*, and the *Canning Trade*. The author is greatly indebted to manufacturers of food preservation equipment and publishers who have kindly donated photographs for illustrative purposes. Specific acknowledgment is made in the text at point of insertion of such illustrative material.

W. V. Cruess.

Berkeley, California,
April, 1924.

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AND
VEGETABLE PRODUCTS

CHAPTER I

MICROORGANISMS IN RELATION TO FRUIT AND VEGETABLE PRODUCTS

The fruit and vegetable products industries depend in most cases upon the control or proper utilization of microorganisms. In the canning of foods, microorganisms capable of causing spoilage are destroyed by heat and their entrance to the food prevented by the use of hermetically sealed containers. Dried fruits and vegetables do not spoil, because they do not contain sufficient moisture to support the growth of microorganisms. In the manufacture of vinegar the growth of yeasts and vinegar bacteria is encouraged, and success depends upon their proper development. Molasses, waste fruit juices, potato mash and other sugary materials are fermented with yeast in making denatured alcohol; and alcoholic fermentation by yeast is used as a preliminary step in the clarification of lemon juice for citric acid manufacture.

In nearly all of the industries to be discussed in this book microorganisms are of importance and must be considered in any thorough presentation of the subject.

RELATION OF FUNGI TO OTHER PLANTS

Microscopic plants are of much greater importance in the horticultural industries than are microscopic organisms of the animal kingdom.

Microscopic plants are placed in two large groups: (1) Fungi, and (2) Algae. Fungi differ from Algae in that they contain no chlorophyll, and from most other plants in that they do not possess chlorophyll, vascular bundles or true roots and do not produce flowers. They are, therefore, much simpler in structure than the higher plants. Their general relation to the higher plants may be seen from the following list of subkingdoms of the vegetable kingdom:

1. *Spermatophyta.*—Flowering and seed-bearing plants. Includes all fruit trees and most cultivated plants.

2. *Pteridophyta.*—Vascular cryptogams; possess leaves, stems, true roots and vascular bundles, but are not true flowering plants. Includes ferns, horsetails, etc

3. *Bryophyta.*—Possess leaves and stems but not true roots or vascular bundles and do not produce true flowers. Includes mosses, liverworts, etc.

4. *Thallophyta.*—No leaves, true roots or vascular bundles. Non-flowering. Under this subkingdom are placed the classes of Fungi and Algae.

Some authors add a fifth subkingdom of *Schizophyta,* or plants that reproduce by fission; and in this group the bacteria and several other types that reproduce by splitting rather than by budding or acrogenous growth are placed. For our purpose, however, the most convenient classification is the one in which the bacteria are placed under a subdivision of the Fungi including two groups, Fission Fungi, and True, or Budding, Fungi.

INDUSTRIAL CLASSIFICATION OF MICROORGANISMS

The complete classification and description of the microorganisms of importance and interest to the manufacturer of horticultural products would be beyond the scope of this book. A brief discussion of the more important forms only will be given. The following classification may be termed an "industrial classification," or classification for industrial purposes, because it includes only the forms of interest to the student of horticultural products and is not arranged in strict accordance with most botanical classifications. It does, however, serve very satisfactorily as a reference table for the subject under discussion.

Classification of Microorganisms of Importance to Horticultural Industries

FUNGI

Fission Fungi

1. Coccaceae (spherical)
   - (*a*) Diplococcus, usually in groups of two cells
   - (*b*) Tetracoccus, in groups of four cells
   - (*c*) Sarcina, in groups of eight cells
   - (*d*) Streptococcus, in chains of cells
2. Bacteriaceae (rod forms)
   - (*a*) Bacterium (plural bacteria), non-motile rod
   - (*b*) Bacillus (plural bacilla), motile rod
3. Fission Yeasts *Schizosaccharomyces*

Budding Fungi

Yeasts (no mycelium)

1. True yeasts (form spores)
   - (*a*) *Saccharomyces ellipsoideus* (wine yeast)
   - (*b*) *Saccharomyces cerevisiae* (beer yeast)
   - (*c*) *Saccharomyces malei* (cider yeast)
   - (*d*) *Saccharomyces pastorianus*
   - (*e*) *Saccharomyces anomalus* (*Willia anomala*)
   - (*f*) *Saccharomyces ludwigi*
2. Psuedo yeasts (no spores)
   - (*a*) *Apiculatus* (*Hansenia*)
   - (*b*) Mycoderma
   - (*c*) Torula

Molds (form mycelium)

1. Penicillium
2. Aspergillus
3. Mucor
4. Botrytus
5. Oidium
6. Monilia
7. Dematium
8. Cladosporium
9. Alternaria

A brief description of the more important properties of the above organisms will be given.

MOLDS

Molds are distinguished by the formation of a mycelium, which is a network of filaments or threads. These threads are termed "hyphae" (singular, hypha) and are usually visible to the unaided eye.

Molds differ from each other principally in their methods of producing spores and conidia; but there are also easily recognizable differences in the appearance of the mycelium and in the nature of the chemical changes induced in media suited to their growth.

Penicillium.—Of the molds given in the foregoing table those of the Penicillium group are the most common and most troublesome to the manufacturer of fruit and vegetable products. C. C. Thom[2] of the U. S. Department of Agriculture has made an exhaustive study of the Penicillium molds.

In the initial stages of growth, Penicillium is white and cottony in appearance. Later, spores or conidia are formed in enormous numbers and give a powdery appearance to the growth, which is blue, or brown, or pink, according to the color of the conidia and the age of the growth.

Penicillium glaucum or more correctly *Penicillium expansum*, is the best known of the Penicillium molds and the one responsible for very great losses to fresh fruit shippers and fruit product manufacturers. It is objectionable principally because of its very disagreeable "moldy" odor and flavor. In young cultures the growth is white and filamentous. The color later turns to blue or green with the formation of spores, and in old cultures becomes brown. The spores or conidia are spherical in shape and are formed in great abundance upon upright hyphae or conidiophores. The conidiophores are branched only in the upper portion. The fructifications consist of a complex system of branches, the ultimate fertile cells of which produce chains of conidia by constriction.

The conidia are light and are carried by air currents. They are universally distributed on surfaces and in the air; all fresh fruits and vegetables carry spores of this organism on their surfaces. This mold will grow on practically all food materials exposed to the air, if the conditions of moisture content and freedom from antiseptics permit the growth of any microorganism. It prefers sugar-containing substances such as fruits, fruit juices, jams, etc., but will develop on such unpromising material as moist leather. Any acid material affords a more favorable medium for growth than does an alkaline or neutral medium.

Growth is most abundant at temperatures ranging from 15 to 25°C. but will occur at temperatures near the freezing point, 0°C., and slowly at temperatures of 35 to 37°C.

Penicillium rocqueforti Thom, *P. camemberti* and *P. brevicaule* are also important members of the Penicillium group.

Aspergillus.—The members of this group are recognized by their peculiar method of conidia formation. The conidia are borne upon

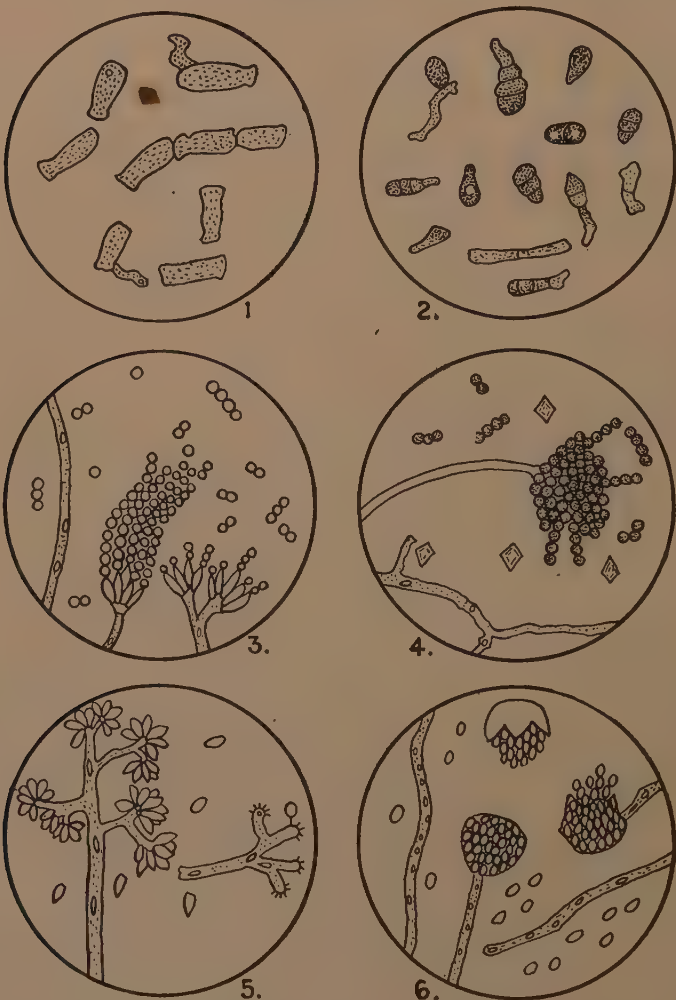

FIG. 1.—Common molds of importance in the horticultural industries: 1, *Oidium:* 2, *Alternaria;* 3, *Penicillium expansum;* 4, *Aspergillus niger;* 5, *Botrytus cinerea;* 6, *Mucor* Species from grapes.

upright conidiophores which terminate in abrupt enlargements or "knobs." From these enlargements spring numerous spike-like projections bearing chains of conidia. The general appearance of an Aspergillus mold under the microscope may be seen in Fig. 1.

Aspergillus niger.—This species is almost as common and as well known as *Penicillium glaucum.* Growth at first resembles that of the Penicillium molds, being white and cottony. After spores are formed in abundance the growth becomes black in color. Unlike *Penicillium glaucum* it does not produce a "moldy" flavor or odor. It is noted for its ability to transform sugars into oxalic acid and under the microscope the acid crystals can often be seen in the mycelium. *Aspergillus niger* has been studied by many biochemists, especially in its behavior toward metallic salts, the formation of oxalic acid serving as a measure of its activity. It is found very frequently on fruits and vegetables and often develops on jellies, jams, marmalades and in insufficiently sterilized fruit juices. It is not utilized industrially.

Aspergillus glaucus.—This mold causes considerable damage to grains, especially barley, during the malting process. It occurs on jellies, preserves and on other concentrated foods and on hay. It readily forms perithecia in such abundance that a yellow color is imparted to the culture. It is not utilized industrially.

Aspergillus repens.—Very similar to *Aspergillus glaucus.*

Aspergillus oryzae.—This species is of fundamental importance to the sake industry of Japan. It is grown on soaked rice, which is later dried at room temperature. The dried product is a mass of spores and is used to inoculate steamed or soaked rice to be used for sake manufacture. The mold converts the starch of the rice into sugar, which may then be fermented to form rice wine or sake. It can also be used to saccharify the starch of potatoes, etc., for industrial alcohol manufacture.

Aspergillus wentii.—This species is used in the Orient, especially in Java, to convert soy beans into various food products.

Many other species of Aspergillus have been described, but the foregoing are the most important from an industrial standpoint.

Mucor.—The molds of this group are widely distributed and several are very common and well known. A general characteristic of the Mucor or "pin molds" is the possession of a unicellular mycelium in which hyphae are not divided by cross-walls or septa. This type of mycelium is often designated as "syphonaceous."

The conidia or spores are borne in spherical sacs known as "sporangia" (singular sporangium), which are usually visible to the unaided eye and each is carried upon an upright fruiting thread or sporangiophore.

The Mucor molds occur very frequently upon fresh fruit, especially during shipment. Grapes often develop a hairy grayish growth of this mold that prevents their sale. Stale breads, if moist, almost invariably develop a vigorous growth of Mucor and on this account the Mucors are often termed "bread molds."

Most members of this group are capable of converting starch into sugar. In sugary liquids under anaerobic conditions yeast-like cells are formed

which convert the sugar into alcohol and carbon dioxide. Very few molds possess this characteristic. Because of their strong diastatic or starch-hydrolizing power several of the Mucors are of great importance industrially.

Mucor rouxii.—This is the most active of the Mucors in transforming starch to sugar. In solid or gelatinous starchy mixtures it develops as a mold; in liquids as a yeast. It is used extensively in Japan to convert rice starch to sugar for fermentation purposes. Several varieties, of which Amylomyces β is well known, are used in Europe and the United States in the manufacture of denatured alcohol from cereals.

Other Mucors.—A number of other Mucor molds are found in the fermentation industries of Asia, among them being *Mucor mucedo, M. circinelliodes, M. racemosus, M. javanicus, M. plumbeus, Rhizopus oryzae* and *Rhizopus javanicus.*

Sclerotinia.—Sclerotinia molds differ from the groups thus far described in that they are parasites; those previously described being saprophytes. The sclerotinia molds are found frequently on fruits, where they may cause very great damage. An example is the brown rot of apricots.

Botrytus cinerea (*Sclerotinia fuckeliana*) may develop upon grapes during rainy and foggy weather as a short, grayish, hair-like growth. The mycelial threads penetrate the grape skin and feed upon the juice. It does not affect the flavor of the grapes but causes rapid evaporation of the water from the juice, which results in a concentration of the sugar content to such a degree that grapes too sour for wine making become sweet enough for the purpose. The sauterne wines of France owe their quality to this fact.

It may also develop upon grapes during shipment and cause loss. Under the microscope the spores are seen to occur in grape-like clusters, as shown in Fig. 1.

Sclerotinia fructigena causes brown rot of various fruits and attacks fruit on the tree or in boxes. It is one of the most widely distributed and destructive of the fungus parasites. It is probably the cause of apricot brown rot in California, a disease which causes serious damage to apricots in the Santa Clara and San Benito valleys. It spoils large quantities of apricots and peaches in lug boxes after picking and is therefore of great concern to the canner.

Oidium.—The molds of this group form conidia by segmentation of the aerial threads or hyphae to form chains of barrel-like or ellipsoidal cells which are termed oidia (singular oidium). Oidium of the vine is a serious grape disease in California and frequently lowers the value of the fruit for juice and other products.

Other Molds.—A number of other molds are of importance or interest to the manufacturer of fruit products.

Monilia molds sometimes represent a stage in the growth of Sclerotinia, but some of the members of this group have not been made to produce all of the forms comprising the complete cycle of Sclerotinia and are, therefore, classed as imperfect fungi. The monilia forms are very common on fruits, the monilia stage of *Sclerotinia fructigena* being the destructive stage of brown rot. The monilia forms are of no use industrially, although some have the property of forming small amounts of alcohol. Monilia produces both mycelium and yeast-like cells.

Dematium pulullans.—This organism develops as a leathery growth of black color and is commonly known as "tree mold." It occasionally develops in fruit juices, rendering them slimy. It forms yeast-like cells and chains of black cells which can easily be recognized under the microscope.

Alternaria is found frequently on fruits, especially on grapes in California that have been left upon the vine until after the fall rains. It appears as a brownish-green growth similar in appearance to Penicillium. Under the microscope the conidiares emble Indian clubs; each is divided by walls as shown in Fig. 1.

Fusarium.—This organism causes wilt of tomatoes and potatoes and is one of the most destructive of the potato diseases. It is recognized by its sickle-shaped conidia.

YEASTS

Alcoholic fermentation, upon which the manufacture of industrial alcohol and vinegar depends, is caused by yeasts. On this account they are of very great importance in certain of the horticultural products industries.

General Classification.—Yeasts are classified in two ways, one upon morphology and the other upon their use in the industries. Thus we have "Culture Yeasts," which are useful in the industries, and the "Wild Yeasts," or all yeasts not useful in the industries. The distinction is sometimes carried further, and a yeast useful in one industry for example, bread making—would in this industry be termed a "culture yeast," while if it should develop in the fermentation of fruit juice it might be termed a "wild yeast." The second method of classification is based upon morphological and physiological properties and especially upon spore formation. Thus, yeasts which form spores are classed as "True Yeasts," and those which do not form spores are "Pseudo Yeasts." All "Culture Yeasts" are also "True Yeasts" but many "True Yeasts" are not "Culture Yeasts," for the reason that many of the spore-forming yeasts are injurious to the quality of products in which they may occur.

In discussing the classification of yeasts we shall consider them under the groups of True Yeasts and Pseudo Yeasts.

The most important group of True Yeasts is that of *Saccharomycetes* in which are found cider yeasts, wine yeasts, industrial alcohol yeasts, beer yeasts and bread yeasts.

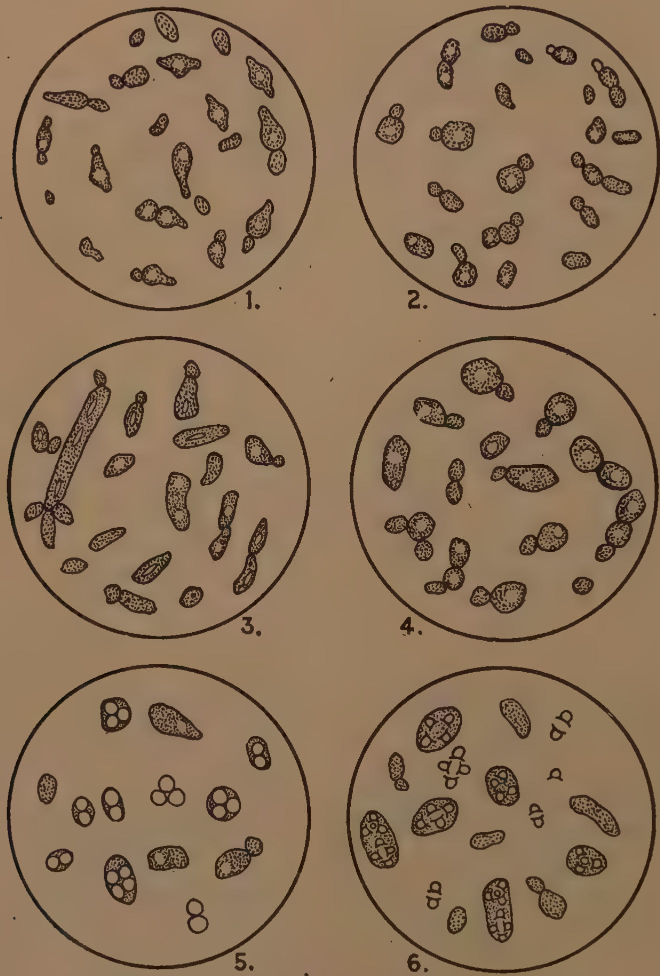

FIG. 2.—Common yeasts of importance in the horticultural industries: 1, *Apiculatus;* 2, *Torula;* 3, *Mycoderma vini;* 4, *Saccharomyces ellipsoideus;* 5, *S. ellipsoideus* with spores; 6, *Willia anomala* (*S. anomalus*) with spores. (*Original*).

Size.—Yeasts are microscopic in size and it is only the very large aggregations of cells that are visible to the naked eye. A cake of compressed yeast contains several billion cells. A cider yeast cell is about 7⁄1000 by 5⁄1000 millimeters in size, or simply 7μ by 5μ.

Multiplication.—An active yeast cell in a favorable liquid will increase in 48 hours to many million cells. Because of this rapid

rate of multiplication, yeasts will often displace other microorganisms particularly molds in a liquid which is favorable to both, a fact which makes possible the rapid fermentation of fruit juices or other sugary liquids.

Spore Formation.—Under conditions of temperature and moisture supply that are favorable for the process, the true yeasts form endospores. Abundant moisture, very little food and a temperature range of 10 to 30°F. favor spore formation. Fig. 2 illustrates the microscopic appearance of spores in a typical wine or cider yeast. Spores have a definite function in the life cycle of the yeast, as they are very resistant to adverse conditions and probably enable the yeast to pass through the winter.

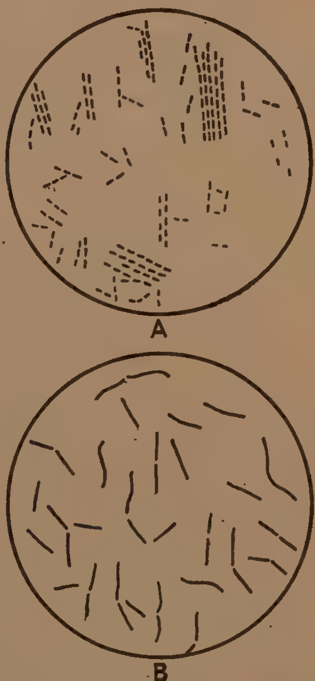

FIG. 3.—*A*, Acetic acid bacteria; *B*, Lactic acid bacteria from pickle stock. Also found in fermented apple juice.

True Yeasts.—Only those yeasts of frequent occurrence and importance in the horticultural industries will be discussed.

Saccharomyces ellipsoideus (Wine Yeast).—Although classed as a wine yeast, this organism is of most importance in the fermentation of all fruit juices for wine, cider, vinegar and alcohol manufacture. The species contains a great number of varieties, many of which have been used in pure culture in the fermentation industries.

Appearance.—The microscopical appearance of vigorous cells is shown in Fig. 2, from an examination of which it will be seen that the shape of the cells varies from spherical to almost sausage-shaped. The usual size of the cells is about 8μ by 7μ.

Spores.—The spores of this yeast are formed in abundance on gypsum blocks. Two to three spherical spores per cell are the numbers usually formed; one or four less commonly (see Fig. 2).

Alcohol Formation.—Most of the yeasts of this species form high amounts of alcohol in liquids containing an excess of fermentable sugar, the formation of 16 per cent alcohol by volume not being uncommon.

A vinous or wine-like flavor is produced in liquids fermented by *S. ellipsoideus.*

Growth and Fermentation.—In liquids containing sugar the first evidence of growth is a slight haziness in the liquid and the formation of a white sediment. As growth proceeds, gas is formed and rises through

the liquid and during active fermentation forms a foam of froth at the surface. The gas carries the cells through the liquid, causing it to become cloudy and at the same time a strong odor of fermentation develops. Near the end of fermentation the sweet taste of the sugar disappears and is replaced by a sharp and alcoholic flavor caused by the alcohol and carbonic acid gas formed from the sugar. After fermentation is complete the yeast cells settle to the bottom of the container to form a compact white or grayish-white sediment. At temperatures of 25 to 33°C., 77 to 90°F., the optimum temperature range for *S. ellipsoideus*, most fruit juices will become completely fermented in less than 3 weeks. This rapidity of fermentation makes this yeast of great value in the manufacture of vinegar and alcohol from fruits.

Occurrence.—Grapes and other fruits carry upon their surfaces and in cracks, cells of *S. ellipsoideus*, but usually these are greatly outnumbered by wild yeasts, as experiments have demonstrated.[3] It is therefore very desirable, and profitable as well, to augment the numbers of *S. ellipsoideus* cells by the addition of a pure culture of this yeast to fruit juices to be made into vinegar or other fermented products.

Saccharomyces cerevisiae (Beer Yeast).—This species is known commonly as beer yeast, but most distillery yeasts and compressed yeasts also are races of *S. cerevisiae*. Just as the *S. ellipsoideus* yeast is the most important fruit yeast, the *S. cerevisiae* yeast is the most important cereal yeast. Because it is used in bread making it is probably the most important yeast used by man.

Appearance.—Under the microscope most varieties of this yeast appear either spherical or egg-shaped.

Saccharomyces cerevisiae cells are usually larger than the average *S. ellipsoideus* cells, the average being about 8μ by 10μ or 9μ by 9μ.

Spores.—The spore formation curves of *S. cerevisiae* (obtained by plotting the time necessary for spores to form, against temperature) have been studied very thoroughly by European investigators, especially by Hansen, the founder of the scientific study of fermentation. As a result of this and other lines of study of this species, many varieties or "races" have been discovered and described. These yeasts are better adapted to the fermentation of cereal products, molasses and potato mash than of fruit juices.

Alcohol Formation.—Most beer yeasts form less than 10 per cent alcohol, but some of the distillery yeasts, 15 to 16 per cent alcohol by volume. Most compressed yeasts used for bread making belong to the distillery yeast type rather than to the brewery yeast group. The compressed yeast easily adapts itself to the fermentation of fruit juices of low sugar content, such as cider, and can therefore be used successfully in fermenting apple juice to be made into vinegar, although yeasts of the *S. ellipsoideus* group are much better suited to the fermentation of all fruit juices.

Saccharomyces sake (Closely related to *S. ellipsoideus*).—It is used in the Orient for the fermentation of rice wort for sake and brandy manufacture. The starch of the rice is converted to sugar by *Mucor rouxii* or *Aspergillus oryzae* and *S. sake* ferments the sugar thus formed to alcohol and carbon dioxide. Both fermentations proceed simultaneously and because of this gradual furnishing of sugar to the yeast by the mold, very high amounts of alcohol are formed. A yield as high as 22 per cent has been recorded.

Saccharomyces malei (apple cider yeast) is often found on fruits. It differs from *S. ellipsoideus* in having a lower alcohol-forming power and in producing a slower fermentation. Because of its slower rate of fermentation and lower alcohol-forming power it is useful in the manufacture of sparkling hard cider. The cells of *S. malei* are usually larger than those of *S. ellipsoideus.*

Saccharomyces anomalus (*Willia anomala*).—Recently this yeast has been placed in a separate genus, that of *Willia*, because of its peculiar spores. It is most commonly known, however, by the name of *Saccharomyces anomalus*. It is recognized by its peculiar hat-shaped spores illustrated in Fig. 2.

This yeast develops as a heavy white film on the surface of sugary liquids. It forms small amounts of alcohol (less than 8 per cent but develops relatively large amounts of aromatic esters, especially ethyl acetate. It may seriously interfere with the normal fermentation of fruit juices and has in the past been very troublesome in distilleries.

Saccharomyces ludwigii occurs very frequently in fermenting apple juice. The cell is very large and lemon-shaped with protuberances at each end, but is very much larger than *S. Apiculatus*, which it resembles in form. It often seriously interferes with the normal fermentation of fruit juices.

Saccharomyces pyriformis is found in ginger beer and resembles *S. ellipsoideus* but is less energetic in its fermentation than the latter. It is of considerable use in making home-made ginger ale.

Saccharomyces pastorianus is a sausage-shaped spore forming yeast occasionally occurring in fermenting fruit juices. It produces a bitter flavor and cloudiness.

Pseudo Yeasts.—The yeasts of this group do not form spores. All are undesirable and not useful in the industries, but because of their great capacity for causing harm during the fermentation of fruit juices, it is desirable to be able to recognize them.

Apiculatus yeast (*Hansenia apiculata*).—This yeast was at one time termed *Saccharomyces apiculatus*, but it is ordinarily not considered as a true *Saccharomyces* because it does not form spores, according to most investigators. P. Lindner has, however, stated that he has been able to cause a strain of this yeast to form spores, one per cell.

Appearance.—In microscopical appearance some of the cells are lemon-shaped, although many of the cells are ellipsoidal, sausage-shaped or even spherical. The cells are very much smaller than those of most yeasts. Because of its shape, irregularity of form and its small size, it is readily recognized and need not be confused with *Saccharomyces ludwigii*, which it resembles in shape but which is much larger than *apiculatus*. *Apiculatus* is normally about 3μ by 5μ in size.

Occurrence.—There are many varieties of *apiculatus*, widely distributed on fruits, cereals and other foods, and it is nearly always present during the first stages of the spontaneous alcoholic fermentation of fruit juices, this stage often being termed the "apiculatus stage" of fermentation. As fermentation progresses *apiculatus* is killed by the alcohol formed by *S. ellipsoideus*. *S. apiculatus* forms only small amounts of alcohol, from 0 to 6 per cent. Those with which the writer[3] has worked formed 2½ to 4 per cent in grape juice.

Control.—The presence of this yeast during alcoholic fermentation is very undesirable, but it can be controlled and eliminated by the use of pure cultures of selected yeasts as described in the chapter on vinegar making.

Mycoderma.—Two species (with many varieties) of this yeast have been described. These are *Mycoderma vini* or "wine flowers," found on fruit juices, pickle brine, etc., and *Mycoderma cerevisiae*, found in breweries and grain distilleries.

Appearance.—These yeasts develop as films upon the surface of sugary or fermented liquids and are extremely common upon fermented cider which is to be made into vinegar and upon wines of low alcohol content. Vinegar manufacturers and wine makers know this growth as "wine flowers."

Effects on Juices.—It destroys not only sugar but also alcohol and fixed fruit acids, and in liquids of low alcohol content frequently destroys all of the alcohol present by oxidizing it to carbon dioxide and water.

Vinegar bacteria form a slimy transparent or translucent rubbery film on the surface of alcoholic liquids, while Mycoderma yeasts form a white, wrinkled film of chalky appearance, which is easily broken. The desirable vinegar film (vinegar mother) can in this way be distinguished from the harmful Mycoderma ("wine flowers") film, even though a microscope is not available (see Fig. 2).

Torula.—These yeasts grow as bottom yeasts and do not form spores. The typical form is spherical, but may vary from spherical to elongated. The Torula group is a "catch all," embracing yeasts of widely different properties, which have in common only the properties of bottom growth and lack of spore formation. They are not useful industrially, but may be very troublesome during the alcoholic fermentation of fruit juices and other liquids. A pink Torula yeast

is very common, being frequently encountered as a contamination upon cultures in bacteriological work and is a cause of spoilage of sauerkraut.

FISSION FUNGI

For our purpose the terms "Fission Fungi" and "Bacteria" are practically synonymous, if the word "bacteria" is used in its broad sense to include true bacteria, bacilli, cocci, spirillae, etc. The fission yeasts are included under Fission Fungi, but are relatively unimportant.

Bacteriaceae.—Bacteria

Bacteria are non-motile rods and do not possess flagellae (organs of locomotion). Some of the most important forms from our standpoint appear below. Classifications are based upon several factors, including morphology, physiological characteristics, and origin.

Vinegar Bacteria includes several distinct forms, such as *Bacterium aceti*, *B. xylinum*, *B. Kützingianum*, *B. Pasteurianum*, etc., all characterized by their ability to convert ethyl alcohol, C_2H_5OH, into acetic acid, CH_3CO_2H, by oxidation. "Vinegar mother" is an agglomeration of these bacteria and is one of the usual manifestations of this organism in fermented fruit juices.

Vinegar bacteria develop normally after alcoholic fermentation is complete. They should not be permitted to develop in vinegar manufacture until the yeast has completed its work, because the bacteria retard and even completely inhibit yeast growth, with the result that unfermented sugar will remain in the vinegar. The bacteria do not, to any appreciable extent, convert sugar directly into acetic acid—yeast fermentation must precede that of the bacteria.

The bacteria may be present as a slimy, tough, almost transparent film or layer on the surface of the liquid, or may be distributed throughout the liquid as individual cells or small groups of cells which give a cloudy appearance to the liquid.

The cells are very small, the usual size being 1μ by $\frac{1}{2}\mu$. Their general microscopical appearance may be seen from Fig. 3.

Lactic Acid Bacteria.—Lactic acid is produced by a number of different forms of bacteria and bacilli. In general, those occurring in milk are motile (bacillus forms), while those occurring in vegetable products are more frequently non-motile (bacterium forms).

Different strains of lactic acid bacteria vary greatly in their properties. Some can withstand a temperature of 60°C. and still remain active; others are sensitive to temperature and cease formation of acid above 37°C. The types of most importance in the cereal products industries, are most active at about 50°C., a temperature at which most other microorganisms cease to function. Thus by merely maintaining the material at 50°C., a nearly pure lactic acid fermentation is obtained. This is

done in "souring the mash" for making compressed yeast and denatured alcohol, where it is necessary that the sugary liquid be acid in reaction in order to promote the growth and activity of yeast and to check the growth and activity of undesirable organisms. Where lactic acid is to be made commercially from cereals, the same method of temperature control is used. The lactic acid bacteria of sauerkraut and pickles are most active at about 30 to 33°C.

Lactic acid fermentations are used in preserving vegetables by fermentation, in the preservation of ensilage, and in the manufacture of many milk products. The spoiling of canned vegetables is often due to lactic acid bacteria. A few spore-bearing organisms capable of forming lactic acid sometimes survive sterilizing temperatures, or leaky cans may admit less resistant forms after sterilizing. Thermophilic bacteria are usually lactic acid formers. These are extremely resistant to high temperatures and cause serious losses in the corn canning industry.

Bacterium mannitopoeum.—This organism is also known as the "Tourne bacterium." It occurs as a wine and cider disease and is perhaps the most serious bacterial disease of fermented fruit juices. Its growth in fermented liquids is recognized by a peculiar "mousey" odor and flavor and a "silky" cloudiness that increases as the disease progresses. It is anaerobic and grows after alcoholic fermentation. It is controlled by proper methods of fermentation and pasteurization of the liquids affected. It is very common in vinegar factories and causes very great damage to both quality and yield (see Fig. 3).

Bacilli.—The bacilli are rod-shaped and motile. A large number of varieties have been described. Most of these are of little interest to the agricultural products industries. They vary in size from those that can barely be seen with the highest powered microscopes to forms that are 10μ to 15μ in length. Some of the more important forms of interest to the horticultural industries are the following:

Bacillus lactis acidi.—This is a short-rod bacillus causing the souring of milk. A related form is *Bacillus bulgaricus*, used in the manufacture of "fermilac" and similar sour milk drinks. *Bacillus lactis* is very active also in the ripening of cheese and in the souring of milk for cheese making. It may also occur in vegetables preserved by fermentation.

Bacillus butyricus.—This is an anaerobic, spore-bearing bacillus used in the manufacture of butyric acid. It occurs in cheese making, in rancid butter, in ensilage and in some spoiled canned vegetables. It produces the characteristic disagreeable odor in beet silage.

Bacillus botulinus.—This organism is a spore-bearing anaerobe of tremendous importance in the spoilage of canned foods. It is a widely distributed and fairly common soil organism. It is heat-resistant and develops in improperly sterilized canned foods, occasionally with

formation of an extremely virulent toxin. (For further details see the chapter on spoilage of canned foods.)

Other bacilli.—Another spore-bearing bacillus of importance to the agricultural industries is *Bacillus mesentericus*, the anaerobe which sometimes causes the spoiling of pickles. It is spore-bearing, of frequent occurrence and is exceedingly resistant to heat. Many other long-rod, spore-bearing bacilli from spoiled foods have been described. Most of them resemble *B. subtilis* and *B. mesentericus* in appearance, etc. *B. sporogenes* is an anaerobe closely resembling *B. botulinus* culturally.

Coccaceae.—The cocci forms are spherical. They are classified largely upon the method of grouping of the individual cells. Numerous varieties exist. Only a few are of importance in food preservation.

Diplococcus.—This form normally occurs in pairs of cells. Sometimes found in spoiled vegetable products.

Streptococcus.—Occurs in long chains of cells.

Tetracoccus.—Occurs in groups of four cells. May be found in fermented fruit juices, causing cloudiness and disagreeable flavors.

Sarcina.—Occurs in "packages" of eight cells each and is found often in fermented fruit juices.

Staphylococcus.—The cells of this group of organisms are grouped in large aggregates. Not of much importance in the industries.

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CHAPTER II

GENERAL PRINCIPLES AND METHODS

A brief discussion of the more important principles and processes underlying the manufacture and preservation of fruit and vegetable products should precede the description of methods of applying these principles industrially.

TEMPORARY PRESERVATION

Some of the most important of the food industries are based upon methods of temporary preservation. The method to be chosen will vary with the product to be held temporarily and with other factors.

Asepsis.—The inception of spoiling of a food product depends largely upon the numbers of microorganisms present. In the handling of fruit for the manufacture of various fruit products care in picking, placing in boxes and in transportation will greatly increase the keeping qualities of the fruit and will usually result in a finished product of superior quality. Dirty lug boxes and rough handling infect and bruise the fruit so that microorganisms are greatly increased in numbers and conditions are made favorable for their growth.

Washing dusty fruit and vegetables before they are used in the manufacture of certain products is often advisable and reduces the number of microorganisms.

Certified milk is made under conditions that tend to exclude most microorganisms from the milk. Its production is a good example of industrial asepsis.

The principle of asepsis is carried to a much higher degree in the manufacture of serums, vaccines and antitoxins. In these cases the absolute exclusion of microorganisms is sometimes accomplished.

Low Temperatures.—Microorganisms are not killed by low temperatures but their multiplication and activities are inhibited. Low temperatures also retard chemical changes.

Enormous quantities of eggs, meats, fruits and vegetables are held in cold storage so that they may be made available for a larger proportion of the year. In all cases the principle involved is the same; namely, the temporary inhibition, by low temperatures, of microbiological and chemical action responsible for decomposition.

Exclusion of Moisture.—Moisture is necessary for the development of microorganisms and the actual growth of mold and other organisms on or in food products takes place in the juice of the product. If the concen-

tration of dissolved solids in this juice or sap exceeds 65 per cent or, that is, if the osmotic pressure exerted by the solution is equal to or greater than that exerted by a 65 per cent sugar solution, the product will usually keep. If moisture collects on the surface of the dried or other product it forms a solution lower in dissolved solids than is necessary to prevent growth. It is in this dilute solution that growth often takes place.

Chemical changes in flour, cereals, dehydrated vegetables, oils, etc., are favored by the presence of moisture; hence these products should be stored in a dry atmosphere.

Mild Antiseptics.—Preservatives such as sugar, salt, sodium benzoate, etc., when used in small quantities, exert only a temporary effect upon the microorganisms of spoilage. Cider is often treated with small amounts of sodium benzoate to preserve it temporarily. Vinegar and spices in ketchup will prevent spoilage, for a time, usually for several weeks after the bottle is opened.

Pasteurization.—When a product is subjected to a temperature which kills a great many, but not all, of the organisms present, the process is spoken of as "pasteurization."

The heating not only kills many organisms, but also greatly weakens and delays the development of those not killed, which is an important factor in the keeping of pasteurized products.

The term "pasteurization" is often applied to the sterilization of fruit juices. In this case, however, it is very probable that all organisms capable of growing in the liquid are destroyed by the heat and preservation is usually permanent.

Exclusion of Air.—The exclusion of air will often prolong the keeping qualities of fruit products. For example, olive oil becomes rancid on exposure to air, but will keep several years if air is effectively excluded. Most fermented products, such as wine, fermented vegetables and green olive pickles, must be sealed in airtight containers to prevent the growth of aerobic organisms which would spoil them.

PERMANENT PREVENTION OF SPOILING

The permanent preservation of food may be accomplished in several ways, most of which depend upon methods of completely eliminating or preventing the activity of microorganisms capable of destroying the product. The method to be adopted will depend upon the character of the material to be preserved and upon other factors.

Sterilization by Heat.—Sterilization by heat means the complete destruction by heat of all forms of life in the product sterilized. In order that sterilized products shall not spoil, they must be sealed in such a manner that all live microorganisms are excluded.

The temperature necessary to sterilize different products varies. The products that are difficult to sterilize are low in acid, often high in protein and contain spore-bearing bacteria. The acidity of fruits, tomatoes and rhubarb greatly lowers the death or sterilizing temperatures of the organisms occurring on these products, which explains why acid fruits are easily sterilized, even if spore-bearing organisms are present.

The effect of hydrogen ion concentration (acidity) is more fully discussed in the chapter on sterilization of canned foods.

Sterilization below 100°C. (212°F.).—Fruit juices are always sterilized commercially at temperatures ranging from 65 to 85°C. Higher temperatures injure the flavor.

One Heating at 100°C. (212°F.).—Fruits are easily sterilized at 212°F. and heating at this temperature is usually for the purpose of cooking the fruit rather than for sterilizing it.

Vegetables, except those of high acidity, when sterilized by one heating, must be heated at 100°C. (212°F.) for 3 to 5 hours to be certain that all spores are killed.

As a general rule, the one-period sterilization of meats and vegetables at 100°C. (212°F.) is unsafe because of danger of survival of spores of *Bacillus botulinus.*

Intermittent Sterilization at 100°C.—The action of heat is rendered more effective if the time of sterilization is divided into three periods, three sterilizations of 1 hour each at 100°C. being much more effective than a single sterilization at 100°C. The sterilizations are generally separated by periods of 24 hours. This method is much safer than the one-heating method at 100°C. for vegetables of low acidity.

Effect of Acidification.—Vegetables and meats acidified with lemon juice or vinegar are easily sterilized. This principle is made use of in the so-called "lemon juice" method first advocated in Circular 158, of the University of California Agricultural Experiment Station. In this method a small amount of lemon juice, vinegar, citric acid or other harmless acid is added to the brine in which the vegetables are canned.

Pressure Sterilization.—The boiling point of water is raised if the water and steam are enclosed in a strong retort. A temperature of 126.6°C. (250°F.) or above may be easily attained, and at these high temperatures the spores of the heat-resistant bacteria are quickly killed.

Permanent Preservation by Antiseptics.—Foods may be preserved permanently by the addition of antiseptics in sufficient concentration to prevent the growth of microorganisms. Some antiseptics, such as sugar, salt and vinegar, are harmless and may be used without reference to the pure food laws. Many chemical preservatives, such as salicylic acid, formaldehyde, boric acid, etc., are harmful to health, if used in sufficient quantity to preserve the food product permanently.

Sugar used in concentrations of 70 per cent or over will permanently preserve most foods, such as fruit jellies, preserves, etc. It acts by osmosis and not as a true microorganism poison.

Salt acts both by osmosis and as a microorganism poison, and for this reason it is much more effective than sugar. About 15 per cent salt is sufficient to preserve most products. *Acetic acid* of vinegar acts as a microorganism poison and is much more active in this regard than salt. About 1 per cent of acetic acid will prevent the spoiling of most products.

Chemical preservatives are still more active. Two-tenths of 1 per cent of sodium benzoate will prevent the spoiling of most food products. Sulphurous acid may often act as a permanent preservative for fruit products when used at a concentration in excess of two-tenths of 1 per cent. Benzoic acid and sulphurous acid are allowed by law if declared on the label. Other chemical preservatives in foods are prohibited in the United States.

Drying.—Preservation by drying depends upon reducing the moisture content to the point at which the concentration of the dissolved solids in the product is so high, 65 per cent or above, that osmotic pressure will prevent the growth of microorganisms.

The amount of drying necessary will depend largely upon the composition of the food. Thus fruits very rich in sugar are not usually dried to as low a moisture content as fruits low in sugar.

The various methods of accomplishing drying will be fully discussed in a later chapter.

Preservation by Fermentation.—Microorganisms may be used for the preservation of foods as well as for their decomposition. *Fermentation* may be defined as the decomposition of carbohydrates by microorganisms or enzymes as contrasted with *putrefaction*, which may be defined as the bacterial decomposition of proteins.

Alcoholic Fermentation.—Alcoholic fermentation by yeast results in the decomposition of the simple hexose sugars into alcohol and carbon dioxide, as indicated by the following reaction:

$$C_6H_{12}O_6 + \text{yeast} = 2\ C_2H_5OH + 2\ CO_2$$

The keeping quality of alcoholic beverages depends upon the presence of the alcohol. Usually air must be excluded from products fermented by yeast in order to prevent the activities of aerobic organisms, such as vinegar bacteria, molds and mycoderma yeasts.

Acetic Fermentation.—Vinegar fermentation follows normal alcoholic fermentation and is brought about by vinegar bacteria. The keeping quality of vinegar is entirely due to the antiseptic action of the acetic acid. The most important use for the preservative action of the acetic acid is for the preservation of various food products, such as pickles, relishes, etc. The reaction involved in acetic fermentation is:

$$C_2H_5OH + O_2 = CH_3CO_2H + H_2O$$

Lactic Fermentation.—Lactic acid fermentation is used very extensively in the preservation of sauerkraut, dill pickles, fermented string beans, etc. Materials that have undergone lactic acid fermentation must be kept sealed from the air to prevent the growth of acid-destroying aerobes; hence the necessity of making silos airtight and of sealing sauerkraut and similar lactic acid fermented products from the air. Lactic acid fermentation is a decomposition of the hexose sugar molecule as indicated by the following reaction:

$$\underset{\text{Dextrose}}{C_6H_{12}O_6} = \underset{\text{Lactic acid}}{2\,C_3H_6O_3}$$

The actual yield of lactic acid is 90 per cent of the theoretical.

Exclusion of Air.—Some food products are spoiled by the simple oxidizing action of the oxygen of the air; others by the action of micro-organisms that require air for their development. Fermented products must be sealed from the air in some manner if the action of mold, vinegar bacteria, Mycoderma yeasts and other organisms is to be prevented. This is especially true of fermented vegetables.

MANUFACTURING PROCESSES

Many of the industrial processes by which fruits and vegetables are converted into more valuable products are not those of simple food preservation, but are highly developed manufacturing processes. The principles of the more important of these are outlined below.

Separation of Valuable Materials from Less Valuable Materials.—A large number of processes are based upon this principle. Of these the more important are:

Crushing and Pressing.—Crushing and pressing of fruits, sorghum and sugar cane result in the separation of the valuable juices and saps from the less valuable pulp and fiber.

Filtration.—Many liquids, such as fruit juices, wines, vinegars, vegetable oils, etc., contain solid material that must be removed by filtration. In most cases the liquid is the valuable portion but in some instances the main value lies in the solid residue. Thus, in the manufacture of citric acid the calcium citrate is a valuable solid and is separated from the lemon juice by filtration.

The simplest filter is the jelly bag of the type used by the housewife in preparing fruit juices for jelly. Paper filters are used for the filtration of olive oil in many factories. Filter presses employing cloth or other filtering medium, wood pulp filters and filters employing asbestos fiber are used. These will be described in Chap. XV.

Flotation.—Materials that are mixed and of different specific gravities may be separated by placing them in a liquid in which one will

sink and the other will float. After the pits have been crushed, apricot hulls and kernels are separated this way. In a similar manner frozen oranges are separated from the sound fruit in running water. Overmature peas may be separated from green peas for canning by use of brines.

Leaching.—Sugar, alcohol and other soluble materials may be separated from fruit pomace, etc., by treatment with water, and oils may be recovered from oil-bearing material, such as olive pomace, by the use of an oil solvent.

Diffusion.—This is a method similar to the preceding and is used mostly in beet sugar manufacture. The sliced beets are surrounded by warm water in a series of tanks known as a "diffusion battery." The sugar diffuses through the cell walls of the sliced beets into the surrounding water and this solution is drawn off and concentrated. The same principle may be applied to other vegetables and fruits. It depends upon osmosis, that is, the tendency of liquids outside and inside the cell to come to the same concentration.

Distillation.—Volatile compounds can be separated from less volatile ones by distillation. Alcohol is separated from water and from other less valuable materials, and in this manner essential oils are recovered from the flowers, herbs or fruits in which they occur.

Types of stills vary greatly in size and design. Most commercial stills for alcohol contain rectifying columns, through which the vapors pass and the columns are maintained at such temperature that the constituents are condensed at different points and separated.

All stills not only vaporize one or more constituents but condense the vapors to liquids again, that is, they consist at least of a still in which the materials are vaporized and a condenser in which the vapors are condensed. By the simple distillation of a fermented fruit juice it is possible to obtain by a single distillation a distillate containing about 60 per cent alcohol; by the use of a rectifying column. it is possible to obtain 94 per cent alcohol by a single distillation.

Some products may be distilled by the direct application of heat to the still; others can only be distilled if a current of steam is passed through the material.

Distillation is the most important process in the manufacture of alcohol, acetic acid, acetone and most essential oils.

Centrifugal Separation.—The tendency for certain materials to separate by the action of gravity is enormously increased by the application of centrifugal force, which is obtained by whirling.

Centrifugal force depends principally upon the rate of spinning of the centrifuge, but is also dependent to a less degree on its diameter. Some centrifuges can be operated at 40,000 revolutions per minute and increase the pull of gravity several thousand times. Thus materials which require

days for settling naturally, will separate almost instantly under powerful centrifugal action.

Some centrifuges are continuous. Other forms are not continuous and must be charged before whirling and cleaned after the operation is completed. Centrifugal force is used in the clarification of fruit juices, the separation of oils from water and fruit juice and of crystals from mother liquors.

Crystallization.—Cream of tartar and certain organic acids, sugars, etc., are recovered commercially by the application of the principle of crystallization. Crystallization depends upon concentration of the solution to such a point that it becomes supersaturated. The solute then separates slowly as very small crystals. As the concentration proceeds these crystals grow in size. They usually separate as pure compounds; however, a certain amount of the "mother liquor" or solution clings to the crystals and then they must be redissolved and recrystallized.

Sifting.—Mechanical sifting is used to separate coarse from fine materials. It is of most use in threshing various cereals, but also may be used in separating grape seeds from the skins and stems, and in other ways in the horticultural industries.

Conversion of Raw Materials into New Products.—Many raw products must be transformed into new products by processes, some of which are chemical in nature and others mechanical.

Fermentation.—Fermentation, one of the most important processes used in the manufacture of valuable products from raw material, may be caused by any one of three main groups of microorganisms classified earlier in this book, *i.e.*, by yeasts, molds or bacteria. The products of fermentation of most importance are alcohol, acetic acid and lactic acid.

Alcoholic Fermentation.—Alcoholic fermentation is essential in the manufacture of denatured alcohol and vinegar and all fermented beverages.

Pure Cultures.—The most important means of control of alcoholic fermentation is by the addition of a starter of the desirable type of yeast. Industrial pure culture methods and other factors will be described in Chap. XXIV.

Other Fermentations.—Other fermentations are controlled by methods similar to those used in the control of yeast fermentation. The details of these methods will be discussed in later chapters dealing with the commercial application of these fermentations. The most important of these fermentations are vinegar fermentation, lactic acid fermentation and the various starch hydrolysis fermentations caused by starch-splitting molds.

Hydrolysis.—The hydrolysis of starch by the use of enzymes or by acids to maltose or dextrose (glucose) is one of the most important hydro-

lyzing reactions used industrially. Malt from barley is most commonly used for the hydrolysis of starch to maltose, and acids are generally used in the manufacture of glucose from starch.

The manufacture of bitter almond oil from apricot, peach and almond pits depends upon hydrolysis of amygdalin by emulsin, an enzyme occurring in the kernels.

Other Processes.—Vegetable oils are refined by treatment with various chemicals and with a current of air or by steam to remove objectionable flavors and odors.

A very important industry, more or less allied to the horticultural industries, is wood distillation followed in the preparation of charcoal. This process is carried out at temperatures which cause the wood to decompose with the formation of wood alcohol, acetone, acetic acid, water and tar which last contains valuable by-products. Charcoal remains in the retort. At some future period it may be profitable to utilize fruit hulls, pits and prunings from orchards and vineyards in this way.

Some organic acids, such as citric and tartaric acid, are recovered from fruit juices by precipitation as insoluble calcium salts.

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CHAPTER III

A BRIEF HISTORY OF CANNING

Canning may be defined as the preservation of foods in hermetically sealed containers by sterilization by heat. In its broader sense it includes preservation by sterilization in glass containers as well as in tin cans.

Discovery of Sterilization.—Although Nicholas Appert is to be credited with the discovery of the art of canning, his discovery was made possible by the investigations of the pioneers of bacteriology; among whom may be mentioned Fracastorius, Leeuwenhoek, Needham, Spallanzani, and Scheele.

The theory of "spontaneous generation" formed the basis of a controversy between the scientists of the period dating from about the middle of the eighteenth century to about 1850 and resulted in the classic experiments of Spallanzani, who first demonstrated that food could be preserved by heat. Those who espoused the spontaneous generation theory believed that microorganisms could develop spontaneously in a sterile medium without the addition of any living cells. For example in 1745, Needham, an English scientist, boiled meat extract in a flask and sealed it airtight. Several weeks later he opened it and found it teeming with bacteria. Since he had boiled the extract, he naturally concluded that he had killed all living organisms present. By sealing the flask he thought he had prevented the entrance of living organisms.

Spallanzani demonstrated the fallacy of Needham's experiments in 1765 by showing that various extracts thoroughly heated in sealed flasks did not spoil, unless "air not treated by fire" entered the containers after sterilizing. Although other scientists did not accept his results as final, he was, nevertheless, the first of whom we have record to preserve perishable food products by heat. He concluded that unheated air was in some way responsible for infection.

Scheele, a brilliant Swedish chemist, in 1782 applied sterilization by heat to the preservation of vinegar by boiling it and sealing it hot in bottles.

Nicholas Appert.—Appert, known as the "father of the canning industry," obtained his early training in confectioners' shops, large kitchens, breweries and distilleries. He was a skilful chef and confectioner before he undertook his investigations in food preservation.

In 1795 he began his studies on food preservation, stimulated by an offer of a prize of 12,000 francs from the French Government for better

methods of preserving food for Napoleon's armies and navy. Not until 1804 was he successful in preserving foods in sealed glass containers. He continued his experiments and in 1810 published his results in a book entitled "The Art of Preserving Foods," which has been translated into English by Mrs. K. G. Bitting.

The essential points of his process consisted in packing the food product into wide-mouth glass bottles with water and corking loosely; placing in a water bath and heating at or near the boiling point for the required length of time; removing the bottles from the water bath and finally sealing by driving the corks tightly into the bottles. He considered glass "as the matter most impenetrable to air," and believed that "external air" as such was the cause of spoilage, although he believed air subjected to heat in the glass jars was not capable of causing spoilage because "it had been rendered of no effect by the action of the heat." He apparently had no clear conception of the relation of microorganisms to spoilage and of the real significance of sterilization.

The results of his work spread rapidly and his methods were soon applied in other countries. It has been claimed that investigators in other countries solved the problem of the preservation of food by heat simultaneously with Appert, or before his discovery. However, it is probable that his work antedates that of others. Incidentally Appert won the prize of 12,000 francs offered by the French Government.

Appert founded a cannery and put his methods to commercial use. The "House of Appert" is still an important canning organization in France and famous for the high quality of its canned products.

Early History of Canning in England and Holland.—In 1807 Saddington published a paper before the English Society of Fine Arts, entitled "A Method of Preserving Fruits Without Sugar for House or Sea Stores." The process was essentially Appert's, in which the fruit was placed in loosely corked bottles and heated in a water bath at 75°C. for 1 hour. After this treatment the bottles were removed, tightly corked and the corks sealed with cement.

In 1810 Peter Durand obtained a British patent for a process of preserving "animal, vegetable, and other perishable foods" by heat followed by hermetical sealing in "vessels made of glass, pottery, tin, or any metal, or fit materials." According to Bitting this is the first mention of use of the tin container for sterilized foods.

Tin containers had been in use in Holland, however, before 1800 for the packing of salted and kippered fish. The fish was not sterilized, but was preserved with brine and smoke and packed into cans which were filled with hot butter or olive oil and sealed.

Early History in America.—Ezra Daggett is credited with being the first canner in the United States. He learned the art in Europe and canned a few salmon, lobsters and oysters in New York. Thomas

Kensett also began the canning of sea foods in New York in 1819. In 1817 William Underwood, founder of the present William Underwood Company of Boston, Mass., came to America from England, where he had served an apprenticeship at pickling and preserving in the plant of Mackey and Company of London. It is not known at what date he started his canning operations, but as early as 1821 he was shipping goods to South America and entries in his sales book for 1822 show that he was in that year selling fruits and berries in glass containers. His sales at first were small because of the prejudice in favor of the English goods, it being necessary to sell in foreign markets at prices below those of the English products, or to sell under an English label. In many cases he consigned his products to sea captains who sold them for him in South American or Oriental ports and purchased sugar or other supplies for him, the captain receiving half the profits.

Winslow.—Corn was first canned by Isaac Winslow, a sea captain of Maine who packed the corn in cans and attempted to sterilize it in boiling water. Most of the cans spoiled, although a sufficient number kept to encourage him to continue his experiments, and in 1853 he attained sufficient success to warrant application for a patent which was regarded with such distrust by the Patent Office that it was not granted until 1862. At first he canned the corn on the cob, but this was so bulky that he resorted to cutting the kernels from the cob. His work and that of the other early canners of corn in Maine gave that state a reputation for the high quality of its canned corn that endures to the present day.

Middle West.—In the Middle West the first cannery of which we have record was established in 1860 by Thomas Duckwall near Cincinnati, Ohio, for the canning of tomatoes. He later canned strawberries, peaches and other products. The world-famous Van Camp Company had its beginning at Indianapolis in 1861. Fruits and vegetables were at first packed in 5-gallon cans and sold to grocers, who opened the cans, sold the products at retail and returned the empty cans to Van Camp. This cannery later specialized in canned beans and soups. After 1876 many canneries were established in the Middle West, until it has now become the principal producing region in the United States for the canned vegetable, especially corn, peas and tomatoes.

California.—In California the first canneries were established in 1859–1860 by Provost and Cutting. Both canneries packed fruits in glass and in tin and shipped them by vessel to eastern ports. Tin plate was imported by vessel from tin plate factories in the East. The industry in California has developed from an output of about 5,000 cases per year in 1860–1863 to an annual production of approximately 15,000,000 cases of canned fruits and vegetables per year. The pioneers in California specialized upon canned fruits, and these are still the most important canned products of that state.

Effect of Civil War.—The problem of feeding the Union armies during the Civil War forced a rapid development of the canning industry. Previous to 1861 sterilization of vegetables and meats had been accomplished in boiling water, which required 5 to 6 hours' time and limited the capacity of the plants to 2,000 or 2,500 cases per day. In 1861 Isaac Winslow found that he could obtain a temperature of 240°F. by adding calcium chloride to the water. He was thereby enabled to reduce the processing time to 25 to 40 minutes for many products. This reduction in processing time greatly increased the output of the canneries and did more than any other single improvement in canning methods to speed up the production of canned foods. Their widespread use by the federal forces did much to popularize canned foods and to stimulate the growth of the canning industry following the close of the Civil War.

History of the Tin Can.—According to Underwood,[3] in the early years of the industry tin containers were known as "tin cases" or "tin canisters." On the cannery books, "canisters" was shortened to "cans," merely as an abbreviation. In time this abbreviation came to be used in place of the longer word "canister." In the British Empire the container is known as a "tin" and canned foods as "tinned foods."

Early Cans.—The first cans were made entirely by hand, the body for each measured and marked on the tin plate and then cut from the sheet by hand shears. The edges were butted together and sealed with a heavy ridge of solder about ⅛ of an inch thick, making what was known as a "plumb joint." The ends of the cans were also marked on the tin with shears. At first the ends were soldered to the bodies by plumb joints without lapping of the tin. Later the edges of the ends were turned up by means of a mallet and a piece of iron known as a "heading stake" and the edges of the body of the can lapped to facilitate soldering and to make a better seal.

In 1823 Angilbert in France improved the method of using tin cans by puncturing as mall hole in the lid. In using, the food was packed into the improved can, the lid soldered in place and the small vent hole allowed to remain open while the can was given a preliminary heating to expel air. The hole was then sealed with a drop of solder.

Can making was formerly an extremely slow process compared with present standards of production. One expert tinker could then produce 60 cans per day; the average was probably less than this. The cans were made in the cannery, there being no can manufacturers who were not also canners.

Improved Solder Cans.—In 1847 a stamping machine for making can ends with extension edges was invented by Allen Taylor and in 1849 the pressed top was invented. In 1876,[4] a machine was invented for automatically soldering the ends to the body of the can by what is known as the "floating" process. About this same date a machine was devised,

which clamped the can body around a horn and lapped the edges so that the can maker had only to apply solder to the seam. One man could seam about 1,200 cans per day with the floating machine. Later, 1885, a side seam-soldering device was added to the body-forming machine and the whole can making process became automatic.

Prior to about 1903 the cans were of the type known as "solder top," or "hole and cap" or "stud hole" cans, whose tops were fitted with circular openings, through which the food was packed. A disc with a small vent hole was placed over the opening and soldered to the top of the can with the small vent open. After a preliminary heating to expel air, the vent was sealed with a drop of solder and the can sent to the sterilizer. At first the discs were sealed to the cans by capping steels and the vents were also sealed by tipping steels both by hand work. Later automatic capping and tipping machines were invented and were used in many large canneries.

Sanitary Cans.—The "stud hole" can has been almost entirely replaced by the sanitary or "open top" can. The ends of this can are fastened to the can body by a "double seaming" operation and an airtight seal is made by a lining of rubber or paper between the end and the body of the can. Double-seamed cans without the rubber or paper gasket were made in 1859 as powder canisters, etc., but it was a number of years later before the principle was applied to the sealing of cans as containers for foods.

Double-seamed cans were first used in Europe. A thick rubber gasket similar to those used in sealing glass jars was placed between the can end and body and the end crimped to the body by rollers. This method was known as the "Karges system" and was demonstrated in America at the Columbian Exposition in 1893. The rubber ring used in this method was cumbersome and costly.

Charles M. Ams[5] conceived the idea of lining the edge of the can end with a rubber solution. This greatly reduced the amount of rubber used, simplified the sealing process and revolutionized can making. Between the years 1894 and 1903 the Max Ams Machine Company developed a line of can making machinery that became commercially successful and following their demonstration of the feasibility of the manufacture and use of this type of can, its use spread rapidly and many improvements in equipment and container were made. Among these may be mentioned the inside lacquered can, which is lined with a special lacquer baked on the tin at a high temperature. This lining protects highly colored fruits and beets against the bleaching action of tin salts.

The solder top cans were objectionable for fruits, because in packing large pieces into the can through the relatively narrow opening much of the fruit was lacerated, and in soldering the cap to the can some of the syrup became carbonized, forming black specks in the syrup.

In the sanitary can the diameter of the opening is equal to that of the can body. Fruits and tomatoes can therefore be packed into the cans without crushing or lacerating. Neither solder nor heat are used in sealing the lid to the can; consequently carbonizing of the syrup is avoided.

Evolution of Sterilizing.—The first canned foods were sterilized in boiling water, in some cases 5 to 6 hours' heating at the boiling point being necessary. As noted elsewhere, the calcium chloride bath was introduced in 1861 and made possible the use of temperatures as high as 240°F., with consequent reduction in processing time.

Pressure Sterilizers.—In 1852 the son of Nicholas Appert adopted the use of the autoclave, *i.e.*, a device for the use of steam in an enclosed space under pressure in canning. This permitted the use of any desired temperature, obviated the cleaning of the cans from the calcium chloride bath and reduced the strain on the cans during sterilization. In 1874, A. L. Shriver, a canner of Baltimore, was granted a patent on a steam pressure retort for the sterilizing of canned foods. The introduction of steam pressure sterilization marked a very great advance in the canning of vegetables.

Continuous Sterilizers.—The continuous open cooker was the next notable advance in sterilizer design. The first continuous cooker used in California for fruits consisted of a long, open wooden tank (often 100 feet long) filled with water maintained at the boiling point by open steam coils. The cans of fruit were carried through the cooker in metal baskets suspended from an overhead conveyor. This method has been superseded by the continuous agitating cooker, in which the cans are carried through a large steam box by means of a reel and spiral in such a manner that the cans roll continuously and thus agitate the contents. Heat penetration, on account of the agitation, is very rapid and the time of processing, therefore, has been greatly shortened for most fruits and for tomatoes.

Recently a continuous agitating pressure sterilizer for sterilizing cans in a retort under steam pressure has been perfected. It permits the use of very high temperatures and a very short sterilization, and will probably revolutionize temperatures and times of sterilization for spinach, pumpkin, corn and other vegetables.

Development of Conception of Sterilization.—The early canners, including Appert, believed that the preservation of canned and bottled foods depended upon the exclusion of outside air, because they found that air sealed in the container and heated became harmless insofar as causing spoiling was concerned. It was believed that air itself caused spoiling of the canned product and that heating in some mysterious manner destroyed its power of causing decomposition. These men recognized the facts in the case, but did not realize that living organisms in the air and not the air itself caused spoiling.

Vacuum Theory.—A later theory was that the vacuum in the can prevented spoiling and therefore great care was taken to make the vacuum as complete as possible by repeatedly heating, venting and sealing the cans to remove as much of the air as possible. The vacuum theory persisted among commercial canners until very recently. It is true that removal of air from the container aids greatly in the preservation of unsterilized fruit and vegetable products by checking the growth of aerobic organisms such as molds. In general, however, a vacuum does not necessarily make sterilizing more easy and its importance in this connection has been overestimated.

Pasteur.—Pasteur by his experiments on pasteurization and sterilization about 1860 definitely proved that microorganisms are the real cause of spoilage and that heating canned or bottled foods preserves them by killing the microorganisms. He found that microorganisms varied in their resistance to heat and that the character of the food product affected the temperature of sterilization. He introduced "pasteurization," *i.e.*, heating food products to a high enough temperature to kill the majority, but not all, of the microorganisms present, thereby greatly prolonging the normal keeping quality of such products.

Pasteur exploded the spontaneous generation theory and showed the fallacy of the vacuum theory.

Early Spoilage Studies.—The first bacteriological study of the spoiling of canned foods in America was made in Wisconsin in 1895 by H. L. Russell, who proved that the heavy spoilage losses experienced by the pea canners of Wisconsin were caused by spore-bearing, heat-resistant bacteria. He isolated the organisms and eliminated most of the spoilage by increasing the temperature of sterilization.

The spoilage of canned corn was studied by Prescott and Underwood in 1896 with results similar to those obtained by Russell with canned peas.

Since the work of these three men, frequent contributions to the knowledge of sterilization and spoilage of canned foods have been made, and most commercial canners are familiar with the fundamentals of bacteriology as applied to canning.

Development of Special Machinery and Methods.—It will not be possible to trace in detail the development of the many special machines used for the preparation of raw products for canning, although in some cases reference will be made in later chapters to the evolution of certain equipment and processes. The canning of corn and of peas has evolved from hand preparation to methods that are conducted almost entirely by automatic machinery. Peaches are no longer peeled by hand, special lye peeling machines now being used; pumpkin is now handled by machinery and special machines have been developed for peeling and coring apples. In general the tendency has been toward the displacement of hand labor by automatic machinery, until today the

commercial cannery has become a large and intricate machine shop, requiring the services of a large corps of skilled mechanics.

An excellent review of the history of canning will be found in "A History of the Canning Industry," published in 1913 by *The Canning Trade,* of Baltimore.

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CHAPTER IV

THE TIN CONTAINER

It is estimated that more than three billion cans are used annually as containers for foods. Cans are manufactured by automatic machinery in large centrally located plants from which they are shipped to the canneries; very few canneries at present make their own cans. Tin plate is made in rolling mills from which it is shipped to can factories located near canning centers.

Tin Plate.—Cornwall was the source of supply of tin of the Romans and remained the principal tin-producing region of the world until recently. The Straits Settlements of southern Asia, however, now supply most of the tin used in the manufacture of tin plate.

Tin plate was invented in Bohemia about 1620 but was not introduced into England until about 1720. Nearly 100 years later, 1810, the first patent for the manufacture of tin cans for foods was granted. The use of the tin container for foods, therefore, is little more than a century old.

Hot Rolling.—Tin plate consists of approximately 98 per cent iron and about 2 per cent tin. Bessemer steel or open-hearth steel of the highest grade and very low in carbon is used.

The preparation of the iron plate begins with bars about 8 to 9 inches wide and 30 to 40 inches long. The "gage" or thickness of the final sheet depends upon the thickness of these bars. The bars are usually $\frac{3}{16}$ to $\frac{3}{8}$ of an inch thick. Two such bars are heated to a cherry red and passed through a set of rolls four times, resulting in two sheets about 30 inches long. These two sheets are placed together, heated to cherry-red and rolled to about 60 inches in length. They are then doubled in the middle, giving four sheets, which are pressed lightly together, heated again, rolled to the required length and allowed to cool. The usual length is 84 inches, which gives three packs of four sheets, 20 by 28 inches each.

Black Pickling.—The pack, four sheets thick, is cut unto three sections 20 by 28 inches in size. The sheets are then carefully separated and placed in a tank of dilute sulphuric acid, known as the "black pickle," which is maintained at the boiling point by steam. The sheets are allowed to remain in the pickling solution until all scale and dirt are removed and are then washed in water. In some cases the sheets are passed through two tanks of acid. The pickling solution dissolves

iron oxide from the surface of the sheet iron, so that the tin will adhere smoothly and uniformly. Imperfectly pickled sheets are sorted out and returned to the pickle after cleaning.

Annealing.—The sheets are next placed on annealing stands holding 4 to 6 tons, and covered with an airtight cast-iron cover. They are then heated to 1,500 to 1,800°F. for 18 to 24 hours with as complete exclusion of air as possible. Annealing toughens the plate and prevents its breaking.

Cold Rolling.—The sheets are then rolled between three sets of polished rolls and heated a second time for a short period and at a lower temperature. Cold rolling makes the surface of the sheets smooth and thus reduces the amount of tin necessary for coating.

White Pickling.—The annealed plates are given a short "pickling" in dilute sulphuric acid and are stored under water until they are turned. This second pickling process is known as "white pickling" and is for the purpose of roughening the surface of the plate slightly, so that the tin will adhere satisfactorily.

Plating.—The tin pot is a U-shaped cast-iron box equipped with two or three sets of rolls and filled with molten tin. A layer of flux floats on the molten tin where the sheets enter the pot and a layer of palm oil where the sheets emerge. In some cases the tin and palm oil are in separate containers. The sheet is drawn through the flux, tin and oil by the rolls. The flux prepares the plate to receive the tin and checks formation of oxide of tin on the surface of the molten metal. The oil gives finish and luster to the plate.

The thickness of the tin coating is regulated by adjusting the distance between the rolls and by the speed with which the sheets are drawn through the bath. The slower the speed the thinner the coating will be, because the longer the plate remains in the tin the hotter it becomes and the smaller the amount of tin which will be chilled to it.

Branning.—The tinned sheets are polished and cleaned in the branning machine, which consists of a series of small rollers covered with wooly sheepskin and running in middlings or bran. The rolls and middlings or bran polish the plate and remove adhering oil.

Grading and Sorting.—The polished sheets are carefully sorted to remove defective sheets for replating and perfect sheets are packed into boxes, 112 sheets per box, which are shipped direct to the can factories.

Grades of Tin Plate.—Ordinary tin plate is known as "Coke plate" and carries about 1½ pounds of tin per base box of 112 sheets 20 by 28 inches in size. Charcoal-A or "Char-A" plate carries about 2½ pounds of tin per base box and is used extensively in cans for fruit canning. Heavier tin plate than Char-A is made but is not commonly used for the manufacture of cans for the food canning industries.

Different weights of plate are designated by letters, *e.g.*, IC, HX, IX, IXX, IXXX, IXXXX, the last being the heaviest of this series and IC the lightest in weight. For example, a box of 225 sheets of IC plate of 13¾ by 10-inch size weighs 147 pounds and the same number of IXXXX plates weigh 203 pounds.

Lacquering.—Highly colored fruits and beets bleach in plain tin cans, but retain their color fairly satisfactorily in lacquered cans.

Lacquer is applied in solution in alcohol to one side of the plate. The plates then travel on an endless conveyor through a long oven where they are heated to about 450° to 500°F. to dry and to bake the enamel or lacquer. Baking causes the lacquer to become a clear golden-brown color.

The lacquered sheets are then formed into cans in the usual manner to give single-lacquered cans. The stamping, lock-seaming, flanging and double-seaming operations used in can making abrade the lacquer more or less and expose the tin in small areas. The interior of some of the cans is sprayed with a solution of lacquer and again baked to give "double-lacquered" cans. These double-lacquered cans are especially desirable for sour red berries, such as loganberries.

Outline of the Manufacture of Sanitary Cans.—The sanitary or open top can, which is sealed by double-seaming without the use of solder, has become the most important food container now used.

Cutting Body Blanks.—The sheets are cut by a slitting machine into strips equal in width to the circumference of the can. These strips are cut crosswise to form the body blanks. The machine used for this purpose is known as a "gang slitter." A slitter and trimmer will produce about 75,000 body blanks per day.

Notching Body Blanks.—Each body blank is notched at the four corners in such a manner that smooth joints are formed at the junction of the two edges of the body, when the lap seam has been made. This smooth union is essential in order that the ends of the can may be smoothly double-seamed to the body without danger of leaks.

Lock Seaming.—The flat can body passes through an edging device, which is usually part of the lock-seaming machine. The edges are turned back and when the can body is turned around the horn or mandrel, these edges hook together. The body is bent around the horn by "wings," moving metal sheets. A hammer drops upon the locked edges and flattens them, forming the lock seam. Since the lock seam is not water and gas tight, the can body is carried forward in such a manner that the seam passes through flux and molten solder. The excess solder is then removed by brushes and the can bodies cooled by a blast of air.

Flanging.—The can bodies next pass through a flanger, a machine equipped with convex plungers, which are forced a short way into the

open ends of the can body, forcing the edges outward to form the flanges, which are to receive the ends.

Forming the Ends.—A machine known as a "scroll shears" cuts the tin plate into strips of a pattern resulting in a minimum of waste.

A stamping machine known as an automatic vacuum "strip feed press" receives the strips and stamps out the discs which form the ends of the cans. It also forms the panels, concentric circular ridges and depressions on the can ends, giving rigidity to the ends and reducing bulging. The edges are still flat. From the press the ends pass to the end-curling machine which curls the edges of the can ends inward.

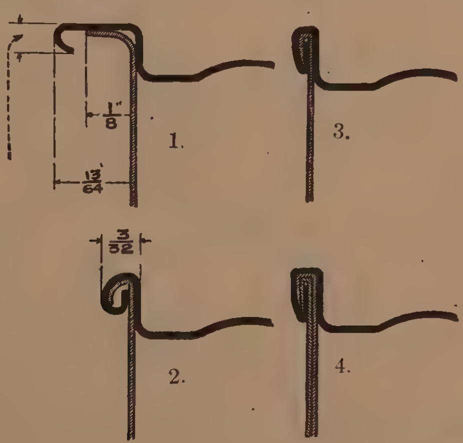

Fig. 4.—Steps in sealing a sanitary can. 1, Lid in place; 2, lid after first operation; 3 and 4, after second operation. (*Courtesy Cameron Can Machinery Company*).

The Gasket.—A solution of rubber in benzene is placed in the groove of the can end and is dried quickly by heat. A film of rubber is left in the groove and forms the "rubber gasket."

Instead of the rubber composition, a paper gasket may be cut from thin spongy cardboard and fitted to the groove.

Sealing the Ends.—The can bodies and one end are brought together in the double-seamer. The can body enters the double-seamer in a horizontal position; the end is applied automatically and small rollers pass around the edges of the end and can body, folding the flanges of the end and can body as shown in Fig. 4, No. 2. A second pair of rollers then passes around the edge of the can and tightly compress the folded flanges together as shown in Fig. 4, 3 and 4. To form an airtight seal, pressure at the same time is exerted against the end of the can, forcing the gasket tightly against the end.

The end sealed to the can in the can factory is known as the "factory end" and that sealed in the cannery, the "cannery end."

Testing for Leaks.—The finished cans are fed to a testing machine, which automatically places the open end of the can against a large rubber gasket and applies 10 pounds or more air pressure per square inch. Leaky cans are thrown out by the machine. These defective cans are tested by hand by workmen who repair the leaks and again test the cans before they are sent to the warehouse or cannery.

Can makers usually guarantee their cans to contain less than 1 defective can in 1,000.

Sizes of Cans.—Tin cans are made in a great variety of sizes and shapes, developed by trade custom rather than by the needs of the consumer. Certain sizes of cans are, however, known as "standard," and the dimensions and capacities of these are given in Table 1.

TABLE 1.—SIZE AND CAPACITY OF STANDARD SANITARY CANS FOR FRUITS AND VEGETABLES

(*After Cruess and Christie's "Laboratory Manual of Fruit and Vegetable Products"*)

Number	Diameter in inches	Height in inches	Capacity in fluid ounces
1 (Eastern oyster)	2 11/16	4	11.6
1 (tall Cal.)	2 11/16	4¼	12.3
1 (flat Cal.)	3	2⅜	16.0
2	3⅜	4½	21.0
2½	4	4¾	31.0
3	4¼	4⅞	35.0
10	6⅛	7	107.0
12	6⅛	8¾	128.0

The No. 2½ square can for asparagus is 3 by 3½ by 6¼ inches and the No. 1 square can for asparagus tips is 3 by 3½ by 3½ inches. The individual service or sample can holds approximately 4½ ounces, the flat salmon about 8 ounces, the No. 1½ flat about 17 ounces, the No. 2 flat about 18½ ounces, the jam can about 20 ounces, the squat pineapple can about 22 ounces and the tomato paste can about 6 ounces. There are other special cans, such as the tall quarts and pints for olives and oval cans for fish.

The No. 2 can is used for peas, corn and string beans and to a limited extent for fruits. The standard can for fruits is the No. 2½. Number 2½ and 3 are used for tomatoes. The No. 10 is used for pie fruits and for fruits and vegetables of all varieties and grades for hotel and restaurant use. The full-gallon (No. 12) can is used for olives and to a very limited extent for other fruits and vegetables. The picnic sizes (No. 2½ squat and No. 2 flat) are becoming more popular for fruits because they are the more suitable sizes for the small family.

The writer believes that the sizes and styles of cans could be reduced to six or seven. The present great number of shapes and sizes of containers is confusing to the purchaser and increases the cost of production, because of the special and extra equipment needed for sealing, filling and otherwise handling the different types of cans.

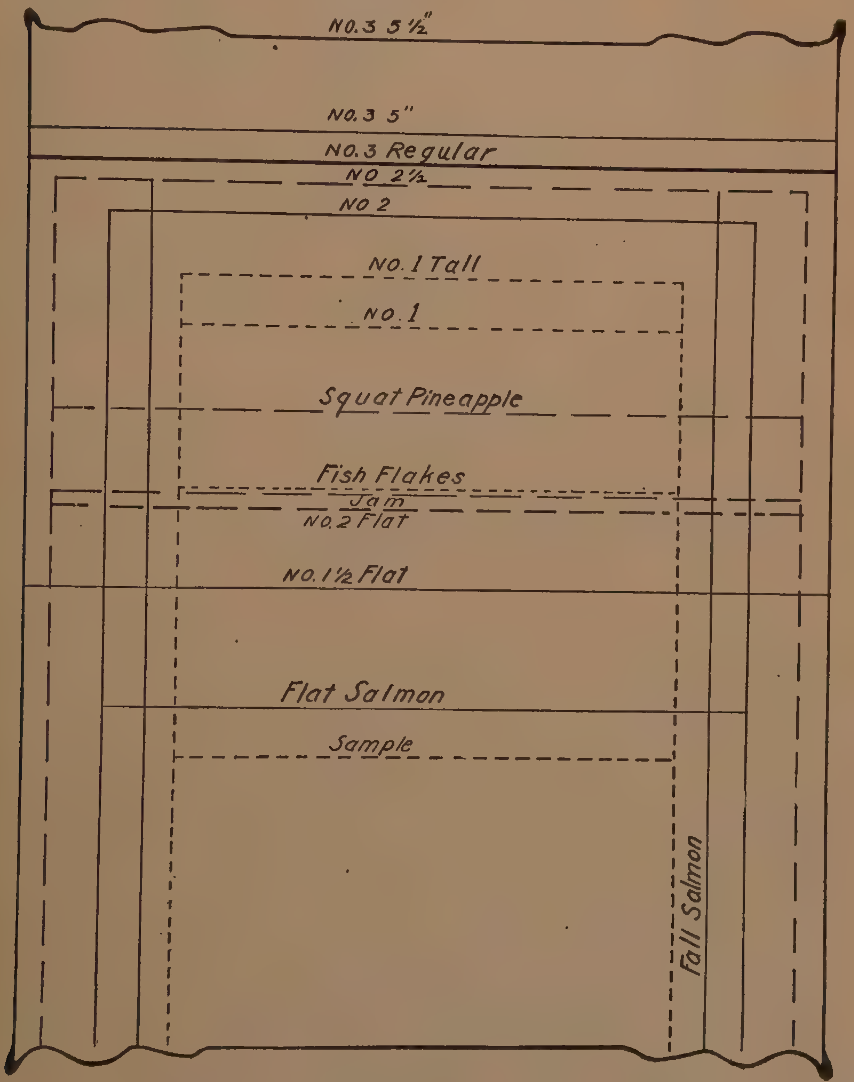

FIG. 5.—Relative size of standard types of cans. (*After Bitting*).

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CHAPTER V

GENERAL CONSIDERATIONS IN ESTABLISHING A CANNERY

In establishing a commercial cannery careful consideration should be given to a number of important factors affecting its location for profitable and efficient operation.

Magnitude of Canning Industry in the United States.—According to the 1919 census there were approximately 4,000 canneries in the United States, of which approximately 3,000 were engaged in the canning of fruits and vegetables. Table 2 summarizes the census data on the food preservation industries for 1919 and 1914.

TABLE 2.—CENSUS DATA FOR THE FOOD INDUSTRIES

Industry	Number of establishments		Value of products	
	1919	1914	1919	1914
Canning and preserving fruits and vegetables...	3,069	3,153	$ 492,625,000	$149,176,000
Canning and preserving fish..................	410	330	77,284,000	31,111,000
Canning and preserving oysters...............	65	65	2,976,000	2,238,000
Condensed milk.........	401	190	339,570,000	69,161,000
Food products not otherwise specified.........	1,998	1,539	662,883,000	219,333,000
Pickles, preserves and sauces................	712	672	144,302,000	60,915,000
Totals.............	6,655	5,969	$1,739,640,000	$531,904,000

The production of some of the more important canned foods is given in Table 3.

The increase in production of some of the canned foods given in Table 3 has been very rapid in recent years; in other cases growth has been gradual. In 1913 the annual output of canned pineapples was 1,667,000 cases. In 1920 it had become approximately 6,000,000 cases per year, an increase of about 400 per cent in 7 years. The California canned fruit

pack in 1900 was 2,873,000 cases; in 1905, 3,450,000 cases; in 1910, 4,774,000 cases; in 1915, 5,731,000 cases and in 1920 it was 11,383,000 cases. Growth was much more rapid from 1915 to 1919 than from 1905 to 1910. Canned tomatoes in the whole United States have shown practically no increase since 1908. Peas have increased from 5,577,000 cases in 1908 to 12,317,000 cases in 1920. The 1908 pack of corn was 6,779,000 cases as compared to 15,040,000 cases in 1920.

Table 3.—Comparative Packs of Some of the More Important Canned Foods, 1920
(Compiled from the *Canning Age*, March, 1921)

Product and Region	No. of cases of 24 cans per case, 1920
Tomatoes, U. S.	11,368,000
Peas, U. S.	12,317,000
Corn, U. S.	15,040,000
Asparagus	1,025,000
Fruits, Pacific district	13,495,000
Fruits, California	11,383,000
Peaches, California	6,753,000
Apricots, California	2,312,000
Pears, California	1,184,000
Pineapple, Hawaiian Is.	6,000,000
Sardines, Maine*	1,878,000
Sardines, California	628,000
Salmon, U. S.	6,289,000

*48 cans per case.

Canning has become an industry comparing favorably in size with the other important industries of America.

Capital.—The establishment of a cannery involves a heavy expenditure of capital and many canneries have failed for lack of it. Usually the return on the investment is not abnormal; nevertheless, it compares favorably with the returns from investments in other well-established industries.

It is desirable to build a plant well within the means of the builder and it is a very much better policy to begin with a small establishment and increase its size gradually than to build a plant which is too great a burden upon the resources of the builder.

It is impossible to give the exact amount of capital necessary for a cannery of given size, but it is ordinarily considered that $2,500 capital is required for each 1,000 cans of fruit per day. This sum will vary with the locality, the length of the canning season, the varieties of fruit canned and other factors.

Raw Products Supply.—In considering the establishing of a cannery one of the most important factors for study will be the quantity and quality of fruit available for canning purposes. The fruit available must be of good quality and of sufficient quantity to permit profitable operation. It should be possible to can the fruit within 24 hours after picking.

Markets.—The principal market for canned fruits in the United States is in the region east of the Rocky Mountains and north of the Mason-Dixon line. Transportation rates from the fruit growing districts of the Pacific Coast to this region are high and fruit canned on the Pacific Coast cannot compete in price with fruit canned in the region mentioned. At the present time, however, fruit grown in this consuming region is not of as high quality as that canned on the Pacific Coast. Ordinarily it will not pay to transport the lowest grades of fruit canned on the Pacific Coast to the Eastern market, because normally these grades of fruit are supplied by the local canneries. On this account canneries of the Pacific Coast have striven to maintain careful grading systems and to produce the maximum quantity of higher grades of canned fruits. It can be seen, therefore, that the cost of transportation and the quality of the finished product are both very important considerations.

Canned fruits are marketed either under the label of the cannery or under those of jobbers, wholesalers or large retailers. Many canners sell practically none of their output under their own label, but rely upon dealers in various parts of the United States to dispose of the goods under dealers' labels. Frequently, it is less difficult to dispose of the pack in this manner than to establish the cannery's own brand. The marketing of canned products under the canner's label, however, is apt to be more nearly permanent and usually permits of more rapid expansion of the business, after the brand has become established.

Length of Canning Season.—The overhead cost of production will be very much less per case of canned product if the canning season lasts 6 months instead of 1. It is therefore desirable to have available for canning purposes several varieties of fruits and vegetables. Tomatoes, peas, string beans, spinach and other vegetables are used by many fruit canneries to maintain the cannery in operation over a long season.

In California the canning season begins with the canning of spinach in March and ends with the canning of tomatoes in November or December. In that state the usual sequence of fruits for canning purposes is cherries, apricots, early peaches, pears, late peaches and tomatoes. Very few berries are canned, but these mature during the early part of the season. In the Middle West and eastern states canneries specialize on single crops, such as tomatoes, peas or corn, to a greater extent than is the case in California.

Labor Supply.—Although the cannery should be located near the orchards or fields if possible, in order that the raw product will not deterior-

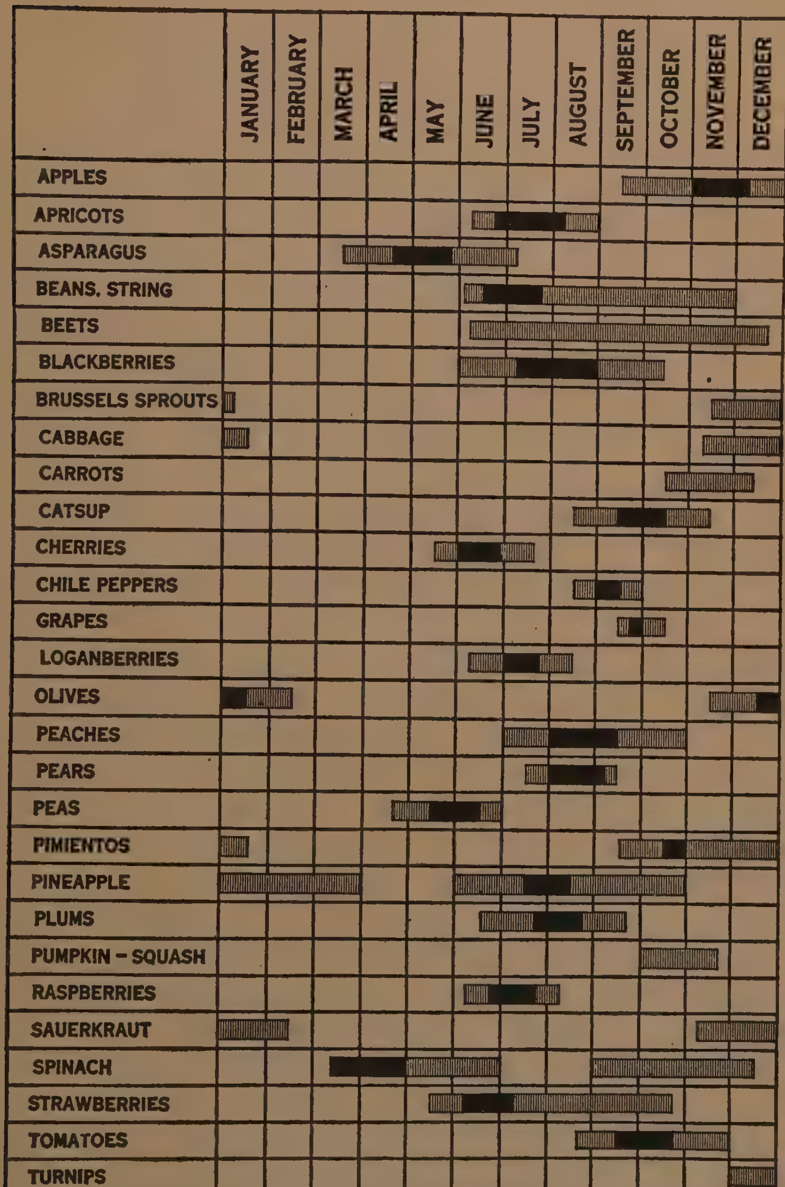

FIG. 6.—Chart showing fruit and vegetable canning seasons in California and pineapple canning season in the Hawaiian Islands. Heavy black lines represent periods of heaviest canning. (*After California Packing Corporation*).

ate in quality between the time of picking and arrival at the cannery, the location of the cannery is often not decided by the source of the raw material, but rather by the availability of labor. The average fruit cannery will require from 400 to 600 workers, ordinarily, about one-third as many men as women and girls. Some of the large fruit canneries, located in the orchard-growing districts remote from large cities, solve the labor problem by building a number of small cottages which are rented at a low rate to the families of the laborers. It is a mistake, however, to locate the cannery at such a great distance from the orchard that serious deterioration of the fruit occurs during transportation.

Transportation.—Both transportation of the raw product to the cannery and the canned product to the market must be considered.

Because of the smooth, broad highways in many states, many of the canneries now transport much of the fresh fruit by truck, which provides very rapid transportation and insures arrival of the fruit at the cannery in firm condition.

If fruit is packed into railroad cars during the heat of the day it ripens rapidly, becomes very soft and may become moldy before it arrives at the cannery. Therefore, it is desirable to load the fruit in the late evening or early morning after it has cooled. Under ordinary conditions it is not economical to ship fruit for canning in refrigerator cars.

Water Supply.—Many canneries are operated upon an inefficient and unsatisfactory basis because of inadequate water supply. The usual tendency is to underestimate the amount of water required and to be careless of its quality. Water for canning purposes should be of good drinking quality, free of any suspicion of sewage contamination and low in mineral salts. Sulphates and iron salts are especially objectionable.

The volume of water required for each ton of fruit canned will vary considerably with the method of preparation of the fruit for canning and with the variety of fruit. Lye-peeled peaches and tomatoes require very much more water than cherries or plums for the reason that very large quantities of water are needed for washing. In one typical California cannery the amount of water used per day is about 100,000 gallons for each 75 to 100 tons of fruit or tomatoes.

The water must be delivered throughout the cannery under heavy pressure because the ability of the water used in washing to remove adhering soil and other foreign material varies with the pressure.

Sanitation.—A clean plant is the first essential in producing canned foods of high quality. The large quantities of waste water, peels and other vegetable and fruit refuse from the average cannery make it necessary to consider carefully the disposal of this waste material in order that it will not become a public nuisance.

The cannery should not be located adjacent to a gas plant, garbage disposal plant or factories that produce disagreeable odors or large quan-

tities of smoke or soot, but should be in a district which is attractive in appearance and so located that the management would not hesitate to invite visitors to inspect it. A sightly and sanitary plant, not only has great value in improving the quality of the output, but also possesses valuable advertising features.

Superintendence.—The maintaining of high standards of quality and the efficient operation of the plant are finally determined by the ability of the cannery superintendent. He must be a man who not only possesses a large amount of technical information, but one who is also able to direct the workmen to the best advantage and who has unusual mechanical ability and an abnormal amount of energy and enthusiasm.

The superintendent must have as assistants thoroughly competent foremen in the different departments. Usually the foremen are men or women who have had a number of years' experience in canning and are thoroughly familiar with the canning operations and equipment and who are able to direct the work of small groups of men or women.

FACTORS IN CANNERY DESIGN

There are certain important factors of cannery construction that should be investigated before the designing and building of the plant are undertaken.

Floors.—Experience has shown that most canneries should be built on one floor rather than on several. The single floor facilitates the work of the superintendent because it is possible for him to have the entire cannery under direct observation at all times. The use of a single floor also facilitates the installation of conveying belts and other conveying systems, thereby reducing labor cost and systematizing the handling of materials.

The floor of the cannery must be waterproof and so constructed that it may be thoroughly washed several times daily. Concrete, which is preferable to wood, must be laid in a single piece and not in sections, as is customary with sidewalks and similar construction, because trucking would otherwise soon cause the floor to break and disintegrate at the points of union between the various sections.

The floors should slope at about $\frac{1}{4}$ to $\frac{1}{8}$ of an inch per foot, but all parts of the floor should be within 20 feet of a drain so that it will not be necessary for the waste water to flow too great a distance. The drains beneath the floor should be large, so that they will not become obstructed by bits of fruit and other refuse.

There is now available a special waterproof cement coating which has proved useful for surfacing cannery floors.

Ceilings and Ventilation.—The cannery roof should be high for good ventilation and so that the shafting will be well above the heads of

the workmen. Good ventilation is particularly necessary in the processing room on account of the large amount of steam liberated during sterilizing.

In addition to providing natural ventilation in this manner, some canners have installed fans to provide artificial agitation of the air. Because the cannery floor is usually wet, the mere movement of the air across the floor causes the air to cool through rapid evaporation of moisture.

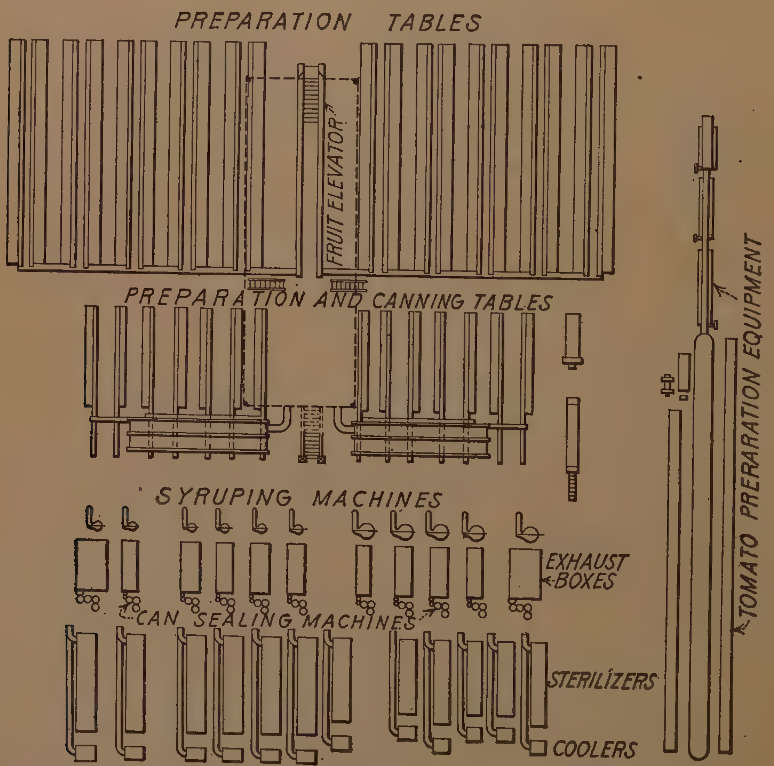

FIG. 7.—Floor plan of a typical fruit cannery in California. (*After Canning Age*).

Light.—The cannery can be more efficiently maintained in a clean and sanitary condition if the interior is well lighted. It is now customary to construct the walls and a large portion of the roof of glass. This so-called "daylight construction" floods the cannery with light throughout the daylight hours, a condition which materially improves conditions for the employees, increases the output per person, and raises the quality of the work.

The painting of the interior of the cannery with a washable variety of white paint increases the light and at the same time makes it possible to detect dirt easily.

It is frequently necessary to operate the cannery at night, and therefore it should be well supplied with powerful artificial lights.

Conveyors.—The installation of conveyors reduces the labor cost of canning and makes the handling of the raw material more prompt and systematic. It is customary to transport the empty cans from the railroad cars to the cannery by special chain conveyors. It is usually possible to install conveying systems to move the peeled or cut fruit from the preparation tables to the canning tables; of canned fruit from the canning tables to the syruping machines; from the syruping machines to the exhaust boxes; and from the exhaust boxes to the can sealers and sterilizers. In some canneries the trucking of the fruit after it has been delivered to the preparation tables is eliminated by the use of suitable conveyors.

Safety Devices.—Most states compel factory owners and operators to install protective coverings for machines that are apt to injure the operators. In cases where this is not compelled by law, the cannery, as a matter of self-protection and to permit the operation of the machines without fear of injury to the workmen, should of its own accord install safety devices.

Steam Supply.—Large amounts of steam are required for sterilizing the canned product, for furnishing hot water and steam used in the preparation of the raw materials, and for sterilizing the machinery. The operation of many canneries is hampered by an inadequate steam supply. A plant which is handling 100 tons of fruit per day should have a steam supply of at least 500 horsepower. It is desirable to have several boilers rather than a single one, in order that cleaning of one of the boilers may be possible during the operation of the plant.

Box Washing Equipment.—Fruit is generally shipped to the cannery in 50-pound lug boxes. Even with the utmost care many of these boxes will become badly contaminated with pieces of crushed and moldy fruit or tomatoes and with fermented juices. This decomposed material will cause excessive spoilage of fresh fruit which is subsequently placed in these boxes, unless the boxes are thoroughly washed and dried before they are returned to the grower. A number of canneries in California have installed special box washing machines to insure that the boxes are returned to the grower in sanitary condition.

Departments.—Canning operations may be naturally divided into three general steps: namely, receiving, preparing for the can and sterilizing.

The fruit enters the cannery through the receiving room, which should be large and conveniently situated with respect to the railroad and truck unloading platforms. It should be separated by a wall from the remainder of the cannery so that it will not become heated with steam from the sterilizing room.

Between the receiving room and the sterilizing room is the preparation room, which should be separated from the other two major divisions of the cannery. This room must be equipped with washable floors and with an abundant supply of water for washing floors and equipment. In the preparation room the fruit is peeled, cored, graded for size, filled into cans and mixed with syrup of the proper concentration. Vegetables are cut, husked, blanched or otherwise prepared and filled into cans.

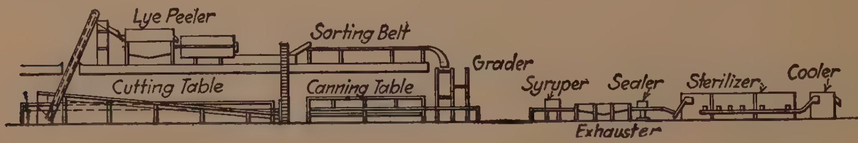

FIG. 8.—Sketch of section of typical California fruit cannery. (*After Canning Age*).

The sterilization room which is always very humid from the escape of steam and considerably warmer than the other rooms in the cannery, should be as completely separated from the preparation room as possible. The exhausting and sterilizing processes take place in this room.

In addition to these three major divisions of the cannery there is a syrup or brine preparation room, which is usually placed above the fruit preparation room. It must be well screened against the entrance of flies or other insects and must be maintained in a very sanitary condition.

The warehouse is usually a separate building, located at some distance from the cannery proper, so that the cans will not be heated or caused to rust by escaping steam from the sterilizing room.

The power plant is also usually in a separate building.

The various departments should be in charge of competent foremen who are all under the direct supervision of a general superintendent. Where responsibility is localized in this manner it is possible to develop efficient operation of the plant.

Cold Storage.—During the rush of the fruit season the cannery may be oversupplied with fruit or vegetables, and raw material sufficient for 5 or 6 days' operation of the cannery may arrive in a single day. Much of this raw material will spoil unless cold storage facilities are available. Some canneries in the past have utilized local commercial cold storage facilities as much as possible, but have found this very costly and troublesome because of the transportation of the raw product to and from the cold storage plant. In order to avoid this inconvenience and to provide ample cold storage space when needed, several of the canneries of the Pacific Coast have installed cold storage plants, which have proved to be very valuable adjuncts to the cannery.

A notable example of a successful cannery-owned cold storage plant is found at the Eugene Fruit Growers' Association's cannery at Eugene,

Ore. The ice plant is used for the manufacture of ice cream and ice in addition to its use during the fruit season for the storage of cherries, peaches and other perishable fruits.

Machinery.—Cannery equipment should be of the best design and construction, and only standard and efficient machinery should be purchased and installed. Some sterilizing machines require a much larger amount of steam than other more modern types of sterilizers. Some recent can sealing machines are much superior to some of the older types still on the market and the same may be said of most of the machinery used in the cannery.

New inventions and improvements in canning machinery have been numerous in the last few years and it will be necessary for the builder to study them very carefully. It will pay him in all cases to visit canneries in operation and to discuss with managers and superintendents the merits and defects of the various machines before he places his orders.

CANNERY ORGANIZATION

Canneries are always operated at high pressure during the rush of the canning season and unless the work is systematized and the superintendent has under his direction efficient foremen in the various departments the cannery will soon be in chaos, or its operation become so inefficient that all possibility of profitable operation is lost. It is necessary to study the operation of the plant very carefully and to plan the work well in advance of the canning season.

The Field Department.—The cannery must have in its service men thoroughly familiar with the growing and picking of fruits and vegetables for canning purposes. In addition they must be able to deal tactfully, yet forcefully when necessary, with the grower so that fruit and vegetables of the best quality shall be taken to the factory and that the products arrive at the cannery when needed. It is one of their duties to see that the cannery has sufficient raw products to operate at full capacity without danger of an undue oversupply.

Receiving Department.—The foreman of the receiving department must be thoroughly familiar with fruit varieties, in order that fruit may be segregated according to variety on its arrival at the cannery. He must also be familiar with the different grades of canned fruit and vegetables in order that a rough grading for quality can be made in the receiving room. He must deal directly with the grower and decide whether the raw product delivered is of high enough quality to be used by his cannery. It will be necessary for him to sample loads of fruits or tomatoes and determine their value for canning purposes. In some canneries the fruit is graded into first, second and third quality, in other cases into two grades only, and the grower paid accordingly.

For example, in 1921 first-grade peaches were accepted in one cannery at $35 per ton, and second-grade peaches at $15 per ton. The foreman of the receiving department must be fair in his dealings with the grower and not take unfair advantage, if the confidence and patronage of the growers are to be retained.

Preparation Department.—In most canneries the preparation department is under the direct supervision of the cannery superintendent, but he is always assisted by a number of foremen and "foreladies," individuals who are thoroughly familiar with the processes employed in the preparation of the raw product and who are at the same time capable of directing the work of the cutters, peelers and other workers. Most of the work in this department is done by women, and women have proved most successful as "foreladies."

Sterilizing Department.—The sterilization of the canned product is the most important in the canning process. The time and temperature of sterilizing will vary with the maturity of the fruit and other conditions. The operation of the sterilizers must, therefore, be directed by a man who is thoroughly experienced in the sterilization of fruits and vegetables and who is qualified to adapt the time and temperature to the needs of the product. Oversterilization will result in softening and deterioration of fruit and most vegetables, and understerilization will result in excessive spoilage. The foreman of the sterilizing room has the greatest responsibility of any individual foreman in the cannery.

Syruping Department.—The preparation of syrup and brine for fruit and vegetables requires great care and a thorough knowledge of the relative quality of the different grades of sugar and salt used in canning operations. Only experienced and careful workmen should have charge of this important operation.

Sales Department.—Many canneries fail because they have not developed profitable markets for their canned products. A well-organized and thoroughly competent sales organization is therefore necessary.

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CHAPTER VI

WASHING, BLANCHING AND PEELING FRUITS AND VEGETABLES

Washing, blanching and peeling fruits and vegetables for canning may be conveniently considered together, since in many instances these operations are conducted simultaneously.

WASHING FRUITS AND VEGETABLES

Water is used for five purposes in the cannery, namely: (1) for the generation of the steam used in sterilizing; (2) for lye peeling, washing, and other preliminary treatment of the raw materials; (3) for the preparation of brine and syrup; (4) for washing the floors, machinery and cans; and (5) for cooling the canned product.

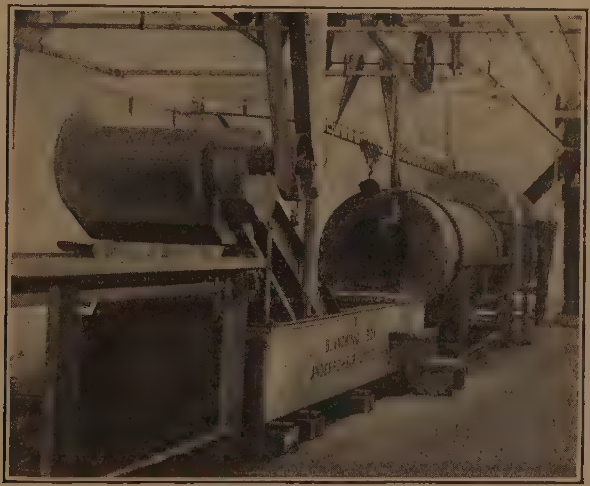

Fig. 9.—Lye peeling machine for peaches. Lye tank at rear, rotary washer in center, blanching box in foreground. (*Courtesy Canning Age*).

Soaking.—Water may be used in three different ways in the washing of fruits or vegetables, that is, by soaking, washing by agitation and by means of sprays. Soaking in itself is not an effective means of removing dirt, but is useful as a preliminary treatment to washing by sprays or by agitation. It is especially desirable for tomatoes, because it softens the sticky coating and renders washing by sprays more effective.

Hot water is a more effective soaking agent than cold water. It is essential that the water be abundant and changed frequently; otherwise, the soaking vat may serve as a source of contamination rather than as a means of cleansing.

Washing by Agitating in Water.—If the fruits or vegetables are agitated in water, the efficiency of the soaking process is greatly enhanced. A very simple form of agitating washer is that used in some factories for the washing of apples for cider manufacture, the apples being conveyed through a current of rapidly running water in a wooden flume.

Compressed air is sometimes used to agitate water in tanks in which the fruit or vegetables are to be washed, or it may also be agitated or circulated by means of a pump. In some cases the soaking vat is equipped with a propeller, which may be in contact with the product, in which case the propeller should move slowly to avoid bruising; or it may be inclosed in a small heavily screened cage at one side of the tank.

The rotary washer used in the lye peeling of peaches is very effective. This consists of a rotary drum or a series of several drums, each of which is equipped with an inner helical conveyor. The drums rotate in tanks of water in which the water is changed continuously or frequently. The spiral carries the fruit progressively through the different washing tanks, the first of which is contaminated with a small amount of lye from the lye-peeling tank while the last two tanks are filled with hot and cold water respectively (see Figs. 9 and 10). This washing device is also used in lye dipping and rinsing of prunes for drying. It has great capacity, does not bruise the fruit badly and is economical of water. It is not, however, so effective or economical of water as the spray system.

Washing by Sprays.—Washing of fruit and vegetables by means of sprays of water is by far the most satisfactory method. Products that are heavily contaminated with soil or other objectionable material should first be soaked thoroughly to loosen adhering soil before washing under sprays.

The efficiency of a spray of water for washing depends upon the pressure of the water, upon its volume and also upon the distance of the spray nozzle from the product to be washed. The spray in which a small volume of water under heavy pressure is used is very much more effective than the one in which a large volume of water under low pressure is employed.

The distance of the nozzle from the product to be washed very greatly affects the efficiency of the spray. Too little attention has been given to this very important detail in some spray washing machines.

Most spray washers consist of pipes that are fitted with hack-sawed openings, but for pressures of water in excess of 20 pounds to the square inch it is advisable that adjustable nozzles be used to prevent unevenness and to direct the sprays in the desired channels. The sprays are effective

only if the water touches all parts of the surface of the product. One means of attaining this object is to place sprays above and below a traveling, woven wire cloth conveyor. The same effect can be obtained by causing the product to roll during the spraying process. The most effective means of agitating the product under the spray is the revolving spray washing machine used on tomatoes and roots. This consists of a slightly inclined perforated drum fitted on the inside with helical spirals or with corrugations. This type of washer is also used effectively in the washing of spinach (Fig. 10).

FIG. 10.—Rotary washer for tomatoes. (*Courtesy, Anderson-Barngrover Mfg. Company*).

The effectiveness of the rotary washer depends upon the speed with which the product passes through the washer, upon the volume of water used, upon the temperature of the water, upon the distance of the sprays from the product and upon the depth of the product in the washer. Many washers are overloaded with such products as tomatoes, with the result that much of the material does not receive the full force of the sprays.

SCALDING AND BLANCHING

Many products are prepared for canning by scalding or by blanching in boiling water. In addition to the other effects produced by this process, the treatment results in a thorough cleansing of the fruit or vegetable. In order to loosen the skins, tomatoes are usually scalded in steam or boiling water for 30 to 60 seconds, followed by immersion in cold water. Asparagus is placed in baskets conveyed through boiling water, which serves as a cleansing and blanching agent. Peas are

always thoroughly blanched in boiling water and in some cases in dilute sodium bicarbonate solution. This removes disagreeable flavors as well as any adhering soil or other objectionable material. Peaches, after lye peeling, are frequently blanched in boiling water or steam to remove the last traces of lye and to destroy oxidase on the surface of the fruit thereby reducing the tendency of the peeled fruit to oxidize. Most vegetables are blanched at some stage of the preparation process in order to remove objectionable flavors, to brighten or fix the color, to improve the texture and for cleansing purposes. More complete descriptions of machines and methods will be given in the discussion of the canning of these various products.

THE PEELING OF FRUITS AND VEGETABLES FOR CANNING

The quality of certain canned fruits and vegetables depends in large measure upon the care taken in peeling.

Hand Peeling.—During the first years of the fruit canning industry in California, peaches were peeled by hand. At the present time very few commercial canners peel the fruit in this manner, but use instead the lye-peeling system.

The knife used for the hand peeling of peaches has a curved blade with an adjustable guide, which permits regulation of the depth of peeling.* The objection to the hand peeling of peaches is that it is very much more costly than lye peeling and is more wasteful of fruit. The hand peeling of vegetables of certain varieties is used in conjunction with various other preliminary treatments which are discussed below.

Pears for canning are always peeled by hand at the same time the fruit is cut in half and the stems, calyces and cores are removed. Peaches and apricots are halved and pitted by hand, although several fairly successful pitting machines are now available.

The Use of Heat in the Peeling of Fruits and Vegetables.—Some varieties of peaches may be peeled by placing the halved fruit on trays in a steam box for 2 or 3 minutes, or by immersing the halved fruit in boiling water for a short time. This treatment loosens the skins so that they may be easily slipped from the fruit with the hands.

Tomatoes are blanched in steam or in boiling water, and then immersed or sprayed with cold water to cool the fruit and to loosen the skins. After blanching and cooling, the tomatoes are easily peeled by hand. Boiling water is probably more desirable than steam as a blanching agent for tomatoes for the reason that it heats them uniformly and cleanses them in addition to loosening the skins. The time for immersion in boiling water is approximately 30 to 60 seconds.

* Peeling and cutting knives are illustrated in Cruess and Christie's "Laboratory Manual of Fruit and Vegetable Products."

Sweet potatoes are steamed under pressure to soften the skin and are then peeled by hand or are lye-peeled.

Beets are blanched in boiling water or in steam until the skin may be separated from the flesh easily. The blanched or parboiled beets are peeled by hand.

Pimientoes are canned in large quantities in southern California and Georgia. Three different methods of peeling are in use. In one process the pimientoes are passed through a revolving steel cylinder which is heated by a direct gas flame. The pimientoes are roasted and the peels may be easily removed from the roasted product by hand or heavy sprays.

The second process consists in passing the pimientoes through a bath of cottonseed oil at about 400°F. This accomplishes the same purpose as the roasting process.

The third process of peeling pimientoes is with dilute boiling lye solution in the same manner as described for the lye peeling of peaches. This is the least satisfactory method and is now seldom used.

Mechanical Peeling.—Apples are peeled in machines that remove the peeling, core the fruit, and, if desired, cut it in spiral slices.

Root vegetables, such as carrots, turnips, parsnips, etc., are peeled in a mechanical peeler consisting of an upright cylinder provided in the bottom with a rapidly revolving disc which in addition to its rotary motion undergoes an undulatory movement. The inner walls of the cylinder and the upper surface of the disc are coated with an abrasive material, such as carborundum. As the disc revolves, water is sprayed into the peeler, washing away the grated peelings and facilitating the peeling process. Usually 1 or 2 minutes' rotation in such a machine is sufficient for peeling.

Lye Peeling.—Lye peeling was probably first used commercially in the production of hominy, when the corn was peeled with lye consisting of the leachings from wood ashes. Corn was boiled in this dilute lye solution until the skins could be slipped from the kernels with the fingers, and the skins removed by washing the lye-treated corn in running water. At the present time hominy is made by boiling corn in dilute sodium hydroxide solution, followed by removal of the skins in revolving cylinders and running water. Usually a small amount of sodium hydroxide remains in the finished product.

Patents.—The application of lye peeling to the preparation of fruits for canning is more recent. The first patent granted for the lye treatment of fruits was in 1901 for a process of dipping prunes in lye to facilitate drying. In this case the lye treatment is not prolonged sufficiently to peel the fruit but merely to check the skins.

The first patent for the lye peeling of peaches and other fruits was granted in 1902. Experiments by M. E. Jaffa, of the University of

California, and others have proved that lye-peeled fruit contains no free alkali, because the small amount of lye remaining in the fruit after washing is neutralized by the acidity of the fruit.

Advantages.—The advantages of lye peeling as compared to the hand peeling of peaches are that: (1) It reduces the cost of peeling; (2) it permits more rapid handling of the fruit; and (3) it causes less loss of fruit by peeling.

Action of Lye.—A boiling dilute lye solution causes the separation of the outer skin of the peach from the flesh beneath the epidermal layer, which is insoluble in the dilute lye. The walls of the cells of the middle lamella cells consist of pectin, which is very soluble in the lye. The parenchyma cells beneath the middle lamella cells of the peach are large and more resistant to the lye than the epidermis. The vascular bundles through the tissues of the fruit are resistant to the lye solution. If the lye-peeling process is carried out satisfactorily, the cells of the middle lamella will be dissolved and the parenchyma cells will be uninjured. If the lye solution is applied for too long a time or is too concentrated, the surface of the lye-peeled peach will be rough and pitted because of the action of the lye on the flesh.

In the lye peeling of sweet potatoes the action of the lye is upon the cutin. The epidermis of the sweet potato is made up of cork cells which are insoluble in the lye solution. Because of the resistance of the epidermis the lye treatment is applied for a longer time than in the peeling of peaches, *e.g.*, 6 to 8 minutes as compared with ½ to 2 minutes for peaches.

Forms of Lye Used for Peeling.—Sodium hydroxide is the most common solvent used in the peeling of fruits. A mixture of sodium carbonate and sodium hydroxide may also be used, although the action of the carbonate is much less vigorous than the action of the hydroxide.

The most convenient forms of the sodium hydroxide are the granular and the flake, either of which should contain at least 95 per cent sodium hydroxide. The manufacturers of sodium hydroxide report its strength to the canner as "per cent sodium oxide," Na_2O. The relation between "per cent Na_2O" and per cent NaOH, sodium hydroxide, is shown in the accompanying table.

It is unfortunate that this system of reporting the strength of canners' lye has come into commercial usage for the reason that sodium hydroxide, and not sodium oxide, is the active agent.

Lye-peeling Machines.—Several forms of lye-peeling machines are in commercial use. The Dunkley lye peeler consists of a long, elevated, rectangular sheet metal box through which a wide, endless, woven wire conveyer carries the halved peaches or other raw material. As the product enters the peeler it is subjected to sprays of hot water. The fruit then passes through sprays of hot lye solution applied to it from

beneath and above the screen. While fruit is not agitated, all portions of the surface are thoroughly acted upon by the hot lye solution. The lye and hot water are held in tanks beneath the peeling chamber and are circulated by means of pumps. After passing through the lye sprays the fruit is subjected to sprays of water. The water used in the first set of sprays is circulated by means of a pump and is used repeatedly, but the final washing of the fruit, is done by sprays of fresh cold water.

TABLE 4.—RELATION OF SODIUM OXIDE TO SODIUM HYDROXIDE CONTENT OF COMMERCIAL SODIUM HYDROXIDE

Per cent sodium hydroxide, NaOH	Per cent sodium oxide, Na_2O
50	38.75
60	46.50
70	54.25
75	58.12
80	62.00
85	65.87
90	69.75
95	73.62
98	75.95
100	77.50

The other manufacturers of peeling machines have made use of the agitation of the lye-treated fruit in water as a means of removing the lye and skins. Machines using this process are those manufactured by the Anderson-Barngrover Company, and the Premier Machinery Company of California (see Fig. 9). Revolving drums carry the fruit first through a tank of boiling lye, then through a tank of hot water and finally through a tank or several tanks of running water. The drums are equipped with inner helical conveyors which carry the fruit forward.

To prevent oxidation of the coloring matter on the surface of the lye-peeled peaches in this latter system of peeling, the fruit in some canneries is carried through a metallic box containing live steam, which heats the fruit thoroughly and destroys the oxidase near the surface.

Concentration of Lye Solution.—The concentration of lye used in the peeling of peaches will vary according to the maturity of the fruit and the type of peeling machine used. The usual concentration is approximately 1½ to 3 per cent.

Length of Immersion in Lye.—In California canneries the length of immersion varies from 20 to 120 seconds. The ripeness of the fruit determines the strength of the lye solution required and the time of immersion. In some factories the time is varied; in others the concen-

tration of the lye solution is varied according to the maturity and variety of the fruit.

The lye solution should be actively boiling because uniformity and rapidity of peeling increase with increase of temperature. For the same reason heating the fruit in boiling water or in steam before it enters the lye solution is desirable and also permits the use of a weaker lye solution.

Amount of Lye Used.—The amount of lye used per ton of fruit varies greatly according to the variety, its maturity and the style of peeling machine used. Most California canners estimate the lye consumption at 7 to 12 pounds per ton of fresh fruit.

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CHAPTER VII

GRADING FRUITS AND VEGETABLES FOR CANNING

One of the most important factors in determining the quality of canned fruits and vegetables is careful grading. It is to be regretted, however, that the labels on canned fruits and vegetables very often do not bear a statement which will indicate to the purchaser the grade of the product in the can, although dealers purchase the canned product from the canner strictly on the grade basis.

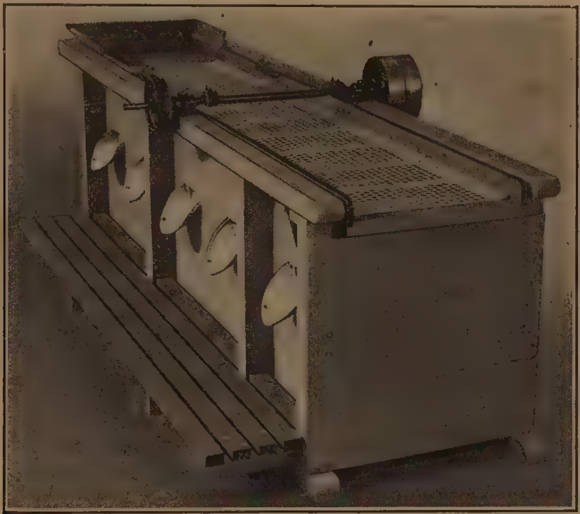

Fig. 11.—Cherry grader. (*Courtesy, Anderson-Barngrover Mfg. Company*).

Objects of Grading.—The grading of the fruit before canning results in greater uniformity of the finished product and in the standardization of methods of canning, sterilizing, etc., thus tending to reduce operating costs.

The advantages of grading have been recognized by practically all commercial canners, and the day when a can contained all grades and sizes of fruit or vegetables is past. It is believed that as soon as the American housewife becomes thoroughly familiar with the different commercial grades, the consumption of canned products will increase.

Effect of Variety on Quality and Grades.—Some varieties of peaches, pears, cherries and other fruits are more desirable than others for canning

purposes. Therefore, in choosing fruit for canning, the proper variety for the purpose should be selected.

Effect of Maturity.—In addition to choosing the proper variety, the canner must make certain that the product is picked at the proper stage of maturity. Fruit for canning purposes is usually gathered when *firm ripe*, that is, not quite ripe enough for table use, but of full size and

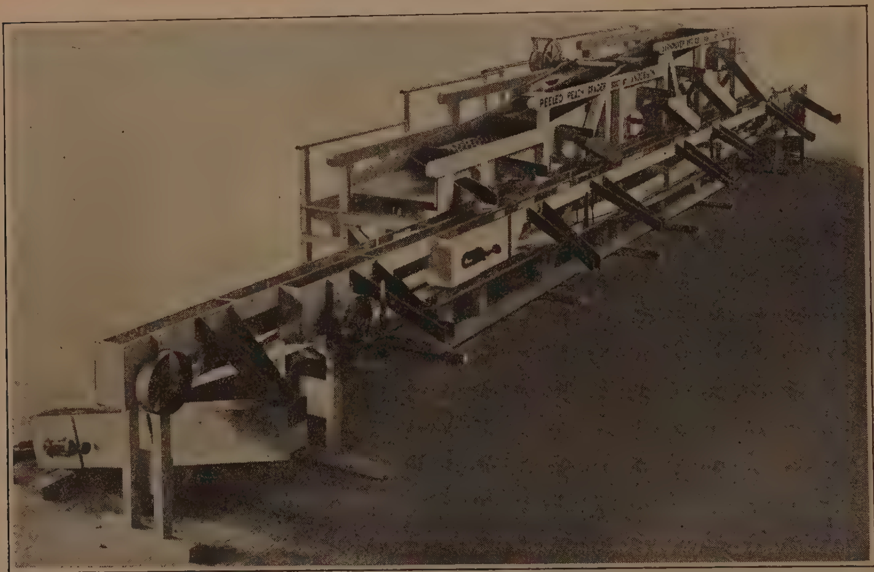

Fig. 12.—Peeled peach grader, also used for apricots, plums and cherries. (*Courtesy, Anderson-Barngrover Mfg. Company*).

with considerable flavor. The term "canning ripe" is well known to the fruit grower and canner, and has come to have a very definite meaning. Immature fruit is lacking in color and flavor; that which is over-ripe is apt to soften badly during sterilization in the can.

The quality of canned vegetables also depends to a very marked degree upon the maturity of the raw material. This is particularly true of string beans, peas and corn. These vegetables must be gathered for canning while still tender.

Importance of Canning Promptly after Picking.—The quality of the finished product is affected very markedly by the length of time which elapses between picking and canning. On this account the raw product should be transferred from the orchard or field to the cannery in the shortest time possible.

Effect of Temperature.—The effect of temperature during shipment to the cannery is also extremely important. Railroad cars used for shipment of canning fruit should be well ventilated and as cool as possible. It is desirable to allow the fruit to stand in the orchard in open boxes

during part of the night to cool before loading into cars. Fruit stored at the cannery should be placed in cold storage or in a well-ventilated room and should be held for as short a time as possible before canning.

Relation of Sanitation to Quality.—Quality is affected by sanitary conditions in the plant. Moldy boxes will often cause spoiling of fruit or tomatoes in shipment or cause them to acquire a disagreeable flavor and odor. Many of the large canneries wash the shipping boxes thoroughly

FIG. 13.—Grading peas in a Michigan cannery. (*After Canning Age*).

in hot sodium carbonate solution in order to clean and disinfect them before returning them to the grower. Floors, canning tables, conveyors, syruping equipment and all machinery in the cannery must be washed frequently and the premises kept free of decomposing cannery refuse.

Grading for Quality.—Upon its arrival at the cannery the fruit should be graded roughly for quality. The over-ripe boxes of fruit should be separated from those of proper maturity. The women employed in cutting and peeling the fruit sort it for quality, usually after peeling or cutting, and it is again sorted on broad, slowly moving belts by women who are trained for this work. A third or fourth sorting is given by the women who fill the cans with the prepared fruit. Careful sorting is essential to success in commercial canning. Vegetables must also be sorted according to maturity, freedom from blemishes, etc. Peas are graded by flotation in brine, according to maturity. Corn must be sorted by hand according to maturity.

CANNING FRUIT GRADES ADOPTED BY THE CANNERS' LEAGUE OF CALIFORNIA

Most of the canners in California grade their fruit according to standards devised and adopted by the Canners' League of California, an

organization comprising over 90 per cent of the canners of northern California. These grades are also recognized by other canners in California not members of the Canners' League. The general specifications for these grades are as follows:

Fancy grade represents fruit of superlative quality, of very high color, ripe yet not over-ripe, free from blemishes, very uniform in size and very symmetrical in appearance.

Choice grade represents fruit of fine quality, of high color, ripe yet not over-ripe, free from plemishes, uniform in size and symmetrical, and is usually one size smaller than the Fancy grade.

Standard grade represents fruit of good quality, reasonably good color, reasonably free from blemishes, uniform in size, reasonably uniform in color and degree of ripeness and reasonably symmetrical.

Second grade represents fruit of second quality, tolerably free from blemishes, tolerably uniform in size, color and ripeness and tolerably symmetrical.

Pie grade represents fruit of pie quality that is wholesome fruit, not suitable to the above grades. It need not be uniform in size, maturity, color or appearance and may contain a few blemishes. It must not contain decomposed fruit.

Table 5 gives the number of pieces of the different varieties of fruit per No. 2½ can, and Table 6 the concentration of syrup used for these different grades.

TABLE 5.—NUMBER OF PIECES PER NO. 2½ CAN FOR VARIOUS GRADES OF CANNED FRUITS AS ADOPTED BY THE CANNERS' LEAGUE OF CALIFORNIA

Fruit	Fancy	Choice	Standard	Second	Pie
Apricots	24 or less, variation 6*	30 or less, variation 7	42 or less, variation 8	No limit	No limit
Cherries, Royal Anne	85	105	145	No limit	No limit
Cherries, other	100	125	175	No limit	No limit
Grapes, Muscat	No standard	No standard	No standard	No limit	No limit
Peaches	6–12, variation 4	6–15, variation 5	6–21, variation 6	No limit	No limit
Pears	6–12, variation 4	6–12, variation 5	6–21, variation 6	No limit	No limit
Plums	11	....	....	....	No limit

* "Variation" refers to variation in number of pieces in different cans from the same factory. Appearance of the fruit and freedom from blemishes are more important in most cases than the number of pieces per can.

TABLE 6.—BALLING DEGREE OF SYRUPS ADDED TO VARIOUS GRADES OF CANNED FRUITS AS SPECIFIED BY CANNERS' LEAGUE OF CALIFORNIA

Fruit	Fancy	Choice	Standard	Second	Pie
Apricots	55	40	25	10	0
Cherries, Royal Anne	40	30	20	10	0
Cherries, other	40	30	20	10	0
Grapes, Muscat	40	30	20	10	0
Peaches	55	40	25	10	0
Pears	40	30	20	10	0
Plums	55	40	25	10	0

These may be considered as minimum standards for the five grades of California canned fruits. Many canners use syrups of higher Balling degree than those given in the table and grade their fruit according to size more rigidly than indicated in Table 5.

CHANGES IN CONCENTRATION OF SYRUP AFTER CANNING

After canning, the concentrations of sugar in the syrup and in the fruit tend to equalize. The heavy syrups, therefore, tend to decrease in Balling degree and the light syrups, if of lower sugar content than the fruit, may increase in Balling degree during storage. There is a fairly definite relation between the concentration of the syrup placed on the fruit at the time of canning and the concentration of the syrup in the fruit and can after canning and storage.

Typical Changes in Concentration of Syrups on Peaches and Pears.—According to Bitting, the following relations exist between the ordinary concentrations of sugar and the final concentration after canning and storage of peaches and pears. The concentration in a can after storage and on examination is known as the "cut-out" concentration.

TABLE 7.—RELATION BETWEEN "CUT-OUT" TEST AND ORDINARY CONCENTRATIONS OF SYRUP USED IN CANNING PEACHES AND PEARS, IN DEGREES BALLING (A. W. Bitting, U. S. Dept. Agr., *Bull.* 196, p. 45)

Peaches		Pears	
Original syrup	Cut-out	Original syrup	Cut-out
55	26.1	40	24.1
40	22.2	30	17.9
30	18.5	20	16.6
20	16.1	10	12.9
10	12.3	0	9.3
0	9.0		

The changes in composition of the syrup are due to osmosis. In most fruits this change occurs without shriveling or without bursting of the fruit although fruits with tough skins, such as grapes, may burst in a very dilute syrup and shrivel in a very heavy syrup.

Relation between Syrup Concentration at Canning and after Storage for California Fruits.—The figures given in Table 8 were obtained from a compilation of published data, principally from Bulletin 196, U. S. Department of Agriculture by Bitting, and must be considered as approximate only, because the composition of the fruit varies with the season, maturity, locality and variety and affects the composition of the syrup accordingly (see also Tables 19 and 20).

TABLE 8.—APPROXIMATE CONCENTRATION OF SYRUP FROM VARIOUS GRADES OF CANNED FRUIT IN DEGREES BALLING

(See also "Laboratory Manual of Fruit and Vegetable Products," by W. V. Cruess and A. W. Christie)

Fruit	Fancy		Choice		Standard		Second		Pie	
	At canning	After storage	At canning	After storage	At canning	After storage	At canning	After storage	At canning	After storage
Apricots, Royal	55	34	40	27	25	20	10	14	0	9
Cherries, Black Tartarian	40	28	30	23	20	18	10	14	0	10
Cherries, Royal Anne	40	26	30	22	20	18	10	15	0	10
Grapes, Muscat	40	28	30	24	20	21	10	17	0	12
Peaches	55	31	40	22	25	17	10	11	0	9
Pears, Bartlett	40	25	30	21	20	16	10	14	0	11
Plums, Green Gage	55	34	40	27	25	19	10	13	0	9

SIZE GRADING OF FRUITS

Cherries, plums, grapes and olives are graded for size whole, while peaches, apricots and pears are graded after cutting in half or after halving and peeling.

Types of Graders.—Most fruits are graded over vibrating screens with circular openings of various sizes. In most cases the thirty-second of an inch is used as the unit of measurement for these holes. The screens are usually five or six in number and are interchangeable so that one machine can be adjusted for different varieties of fruits by simply inserting the size of screen adapted to the fruit. The screens are usually made of copper, as it has been found that this metal will withstand severe use and does not injure the color of the fruit.

Screen Graders.—In some graders the large sizes of fruit are removed first. This is accomplished by allowing the smaller sizes to fall through the first screen and permitting the largest size to pass over

the end of the first screen, where the fruit is conveyed to the canning tables by a belt operating at right angles to the direction of flow of the fruit. In a similar fashion the lower grades of fruit are separated.

In the second style of grader the small sizes are removed first and the largest size is allowed to drop progressively from one screen to the next and finally to pass over the last screen. This is considered objectionable because the large fruit is subjected to unnecessary agitation which may result in softening or bruising. This is particularly true of delicate-textured fruits, such as halved apricots.

Roller Grader.—The "roller" grader consists of two rollers, usually about 2 inches in diameter, which revolve toward each other and which are closer together at the upper end than at the lower end. As the fruit passes along these rollers the small fruit is the first to drop through and is removed. The largest sizes are removed last. This style of grader is suitable for spherical, unpeeled, uncut fruit. It has been used more or less successfully for the grading of whole peaches, apricots and olives.

Grading by Weight.—A recently developed grader for apples and oranges grades the fruit by weight. The individual fruits fall into traveling canvas pockets placed at one end of short, counterpoised rods. The rods rest on a long iron strip which serves as a fulcrum. As the fruit is carried along the grader, the distance of the fruit from the fulcrum becomes greater. The cups tilt as the leverage of the fruit becomes greater than that of the counterpoise. The heaviest fruit is removed first and the lightest fruit last. This grader has proved very popular for apples and may have possibilities for grading other fruits for canning.

Pears are graded by hand after peeling, halving and coring.

Diameters of Openings in Grader Screens for Common Fruits.—The usual diameters of the higher grades of canned fruits are shown in Table 9. There are no size standards for second and pie grades.

TABLE 9.—AVERAGE DIAMETER OF VARIOUS GRADES OF CANNED FRUITS (EXCEPT OLIVES)

(After Cruess and Christie's Laboratory Manual of Fruit and Vegetable Products)

Fruit	Fancy	Choice	Standard
Apricots	$^{56}/_{32}$ inch	$^{54}/_{32}$ inch	$^{50}/_{32}$ inch
Cherries, Royal Anne	$^{29}/_{32}$ inch	$^{28}/_{32}$ inch	$^{28}/_{32}$ inch
Cherries, Black	$^{26}/_{32}$ inch	$^{25}/_{32}$ inch	$^{22}/_{32}$ inch
Grapes, Muscat	$^{26}/_{32}$ inch	$^{25}/_{32}$ inch	$^{24}/_{32}$ inch
Peaches	$^{76}/_{32}$ inch	$^{64}/_{32}$ inch	$^{56}/_{32}$ inch
Plums, Green Gage	$^{56}/_{32}$ inch	$^{50}/_{32}$ inch	$^{42}/_{32}$ inch
Pears, Bartlett*	8–10 pieces	10–12 pieces	15–17 pieces

*Pieces per no. 2½ can.

Normally the sizes of the various grades of fruit are equal to or greater than the diameters given in the table.

Owing to the fact that ripe olives vary greatly in form, it is customary to grade this fruit according to the number of olives per pound as indicated in the following table.

TABLE 10.—SIZE GRADES FOR CALIFORNIA RIPE OLIVES, AS DEFINED BY THE CALIFORNIA OLIVE ASSOCIATION

Grade	Approximate diameter, inch	Number of olives per pound
Small	9/16	120–150
Medium	10/16	105–120
Large	11/16	90–105
Extra large	12/16	75–90
Mammoth	13/16	65–75
Giant	14/16	55–65
Jumbo	15/16	45–55
Colossal	16/16 or above	35–45

Size Grading of Vegetables.—Peas, string beans, beets, cucumbers and asparagus are graded for size, in some cases by screens and in others by hand. The method of grading and grade designation vary with the vegetable concerned. Therefore, in order to avoid undue repetition, vegetable grading and tables of size grades will be given in the discussion of canning of the individual vegetables.

GOVERNMENT STANDARDS FOR NET DRAINED CONTENTS

The Bureau of Chemistry of the U. S. Department of Agriculture has established standards for net contents of cans of certain fruits and vegetables. The investigations upon which these standards are based have been made by the various food and drug inspection laboratories of the Bureau of Chemistry.

The standards as at present established are to be considered as minimum requirements, and in most cases products canned by the usual commercial methods will readily meet or exceed these minimum standards.

The determination of the net drained weight of canned fruits and vegetables is made according to the following directions of the Bureau of Chemistry.

Draining.—For determination of drained weight the contents of No. 2½ cans and cans of smaller size should be emptied on a circular ⅛-inch mesh screen 8 inches in diameter, set in a frame with a vertical side higher than the

level of the product on the screen. The contents of the can should be distributed over the screen so as to form a layer of uniform depth, this being accomplished so far as possible by the manner of emptying from the can. Such further handling as is required to level the material on the screen, in order to secure a layer of practically uniform depth, should be done in such a way as to exert no pressure, whereby additional amounts of liquor will be expressed from the material. The period of draining should be 2 minutes in all cases. The manner of determining the drained weight for No. 10 cans is the same as the foregoing, with the exception that a circular ⅛-inch mesh screen 12 inches in diameter is used. This screen should also be set in a frame with a vertical side higher than the level of the product on the screen.

Cans of sizes not mentioned should yield a drained weight of contents which bears the same relation to the drained weight indicated for the can nearest in size as that existing between the capacities of the cans in question.

In making declarations under the net weight requirement of the Federal Food and Drugs Act, the total weight of the contents of the can, liquid included, should be declared; this Bureau will regard as in violation of the Act interstate shipments of canned foods packed with lighter weights than those indicated. May 5, 1920.

Standards as at present published can be obtained on application to the Bureau of Chemistry, U. S. Department of Agriculture, Washington, D. C.

References

1. "Specifications for California Canned Fruits," Issued by the Canners' League of California.
2. Alsberg, C. L.: Cut-out weights of canned foods, *The Canning Trade Almanac*, 1922, pp. 17–29.

CHAPTER VIII

SYRUPS AND BRINES USED IN CANNING

In canning, syrups are added to fruits and brines to vegetables to improve the flavor, fill the spaces between the pieces of canned product and to aid in the transfer of heat during sterilization. They also fill the can more or less completely, thereby excluding air, the presence of which causes corrosion of the tin plate.

Sugars Used in Canning.—The principle sugar used in canning is sucrose, that is, cane sugar, or beet sugar. Cane and beet sugars are identical in chemical composition. In most cases commercial cane or beet sugar contains more than 99 per cent sucrose. The prejudice against beet sugar for canning and preserving has been caused probably by the fact that during the first years of the beet sugar industry the product was not always of the highest purity and sometimes contained considerable beet molasses, which adversely affected the flavor of the sugar. The beet sugar produced at present is highly refined and free from objectionable flavor or odor. Many canners, as a matter of fact, use beet sugar because it is cheaper.

Centrifugal Sugar.—An impure grade of cane sugar, known as Central American sugar or centrifugal sugar, is often used in the canning of fruits of dark color and where the amber color of syrups made from such sugars would not be an objection. Such fruits as yellow peaches, apricots, berries and black cherries may be canned with this sugar. It cannot be used for pears unless decolorized by bone black before use.

This sugar is considerably cheaper than refined sugar, but varies greatly in sucrose content and may contain as little as 85 per cent sucrose, the principal impurity being molasses. The purity can be roughly judged by the color of the syrup. Such a rough estimate of the purity, however, should be checked by chemical analysis or by polarization of an average sample.

Another grade of cane sugar is the "plantation clarified," which is usually a high grade of the centrifugal sugar, often equal to the highly refined sugar in purity.

Unrefined centrifugal sugars may occasionally contain sulphur dioxide, which may form hydrogen sulfid in the cans and a black deposit of metallic sulphid.

Invert Sugar.—The principal sugar in all of these commercial sugars is sucrose, $C_{12}H_{22}O_{11}$, which on hydrolysis yields equal amounts

of glucose and fructose. The hydrolyzed product is known as "invert sugar."

For some purposes cane sugar is dissolved in water, inverted with invertase and concentrated to a heavy syrup.

Glucose.—Corn sugar, or glucose, in granulated or crystal form, but more frequently in the form of a heavy syrup, is sometimes used in the cannery for the cheap grades of canned fruits and in the manufacture of cheap jams and jellies. It is very much less sweet than cane sugar and is produced from cornstarch by hydrolysis under pressure with dilute hydrochloric acid and possesses the chemical formula of $C_6H_{12}O_6$.

FIG. 14.—Syrup room in a fruit cannery. Square tank, upper left, is used for preparing concentrated syrup and small, circular tanks for syrups diluted for addition to cans.

Preparation of Syrups for Canning.—In most canneries the syrup preparation room is located on the floor above the fruit preparation and canning rooms and the syrups are transferred by gravity through pipes to the syruping machines. The sugar is dissolved in a small amount of water to yield a heavy syrup, usually of 60 to 65° Balling or Brix. Glass-lined, that is, enamel-lined steel tanks have been found most satisfactory for the syrup. The tank in which the heavy syrup is prepared is fitted with a steam heated copper coil or open steam jets and the water and sugar are boiled together until a clear syrup is obtained. Some impurities coagulate and are removed by skimming and the heavy syrup is further clarified by passing it through several thicknesses of cloth before it is transferred to the diluting vats. (See Fig. 14.)

The mixing tank for the heavy syrup is located above the reservoirs or diluting vats, of which there are usually four or eight. In these vats

the syrup is diluted by mixing measured quantities of the heavy syrup with water to give the desired Balling degree. The grades of syrup used for the different fruits have been given in Table 7.

Testing the Syrup.—The syrup must be tested accurately before use so that the syrup in the cans will be of uniform composition and the cut-out test not be above or below the established standard. In large fruit canneries 25,000 to 50,000 pounds of sugar per day are used. If the syrups used average 2 per cent too high in sugar content this will correspond to a loss of 500 to 1,000 pounds of sugar per day.

FIG. 15.—Balling (or Brix) hydrometer, cylinder and thermometer for testing syrups.

The instrument commonly used in canneries for the testing of syrups is the Balling hydrometer, which gives the per cent of sugar in the syrup, providing the syrup is tested at 15½°C., or 60°F. Temperatures higher than this cause expansion of the liquid and too low a reading. It is, therefore, practically always necessary to make a temperature correction.

Brix and Baumé.—The Brix hydrometer is similar to the Balling hydrometer but is standardized at 17½°C. The Baumé hydrometer used in some canneries was originally designed for the determination of salt in brines and was originally calibrated by determining the resting point of the hydrometer in water, which was taken as zero on the scale, and the resting point in a 10 per cent salt solution, which was taken as 10° Baumé. Points above or below 10° were divided into equal scale divisions.

Testing Hydrometers.—Owing to the fact that continued use of the hydrometer in hot syrups affects its accuracy, it should be checked frequently by more accurate instruments. Hydrometers with long stems, and therefore of greater distance between divisions, are more easily read than hydrometers with short stems. It is desirable for the canner to have duplicate or triplicate sets of accurate hydrometers. Table 11 gives the relation between specific gravity, Balling degree and Baumé degree.

TABLE 11.—RELATION OF BALLING, SPECIFIC GRAVITY AND BAUMÉ

(For complete table see "Methods of Analysis," Association of Official Agricultural Chemists, Washington, D. C.)

Balling degree or Brix	Specific gravity	Baumé degree	Balling degree or Brix	Specific gravity	Baumé degree
1	1.0038	0.55	38	1.1692	20.80
2	1.0077	1.10	39	1.1743	21.40
3	1.0117	1.70	40	1.1794	21.90
4	1.0157	2.20	41	1.1846	22.40
5	1.0197	2.80	42	1.1898	23.00
6	1.0237	3.30	43	1.1950	23.50
7	1.0277	3.90	44	1.2003	24.00
8	1.0318	4.40	45	1.2056	24.60
9	1.0359	5.00	46	1.2110	25.00
10	1.0401	5.55	47	1.2163	25.60
11	1.0443	6.10	48	1.2218	26.10
12	1.0485	6.70	49	1.2272	26.70
13	1.0527	7.20	50	1.2327	27.20
14	1.0570	7.80	51	1.2383	27.70
15	1.0613	8.30	52	1.2439	28.20
16	1.0656	8.90	53	1.2495	28.75
17	1.0700	9.40	54	1.2551	29.30
18	1.0744	10.00	55	1.2608	29.80
19	1.0788	10.50	56	1.2665	30.30
20	1.0832	11.10	57	1.2723	30.80
21	1.0877	11.60	58	1.2781	31.30
22	1.0923	12.20	59	1.2840	31.85
23	1.0968	12.70	60	1.2898	32.40
24	1.1014	13.30	61	1.2958	32.90
25	1.1060	13.80	62	1.3017	33.40
26	1.1107	14.35	63	1.3077	33.90
27	1.1154	14.90	64	1.3138	34.40
28	1.1201	15.40	65	1.3198	34.90
29	1.1248	16.00	66	1.3260	35.40
30	1.1296	16.50	67	1.3322	35.90
31	1.1344	17.10	68	1.3384	36.40
32	1.1393	17.60	69	1.3446	36.90
33	1.1442	18.50	70	1.3509	37.40
34	1.1491	18.70	71	1.3572	37.90
35	1.1541	19.20	72	1.3635	38.30
36	1.1591	19.80	73	1.3699	38.80
37	1.1641	20.30	74	1.3764	39.30

Before removing samples from the syrup tank the contents of the tank should be thoroughly mixed. Compressed air may be used to advantage in stirring. In reading the hydrometer the bottom of the meniscus (level of the syrup) is read.

Effect of Impurities.—Carbonates and sulphates in the water used in preparing syrup may cause white precipitates during boiling. Iron salts in the sugar may cause darkening of the syrup or precipitation in the can. Soft water is therefore preferable to hard water in the preparation of syrups for canning.

Spoiling of Syrups.—If the syrup is used during the day upon which it is prepared, there is little danger of spoiling. If, however, the pipes between the syrup tank and the syruping machines are allowed to stand several days unused and uncleaned, enough yeast or bacteria may develop to cause disagreeable flavors, ropiness or fermentation.

On this account syrup lines and tanks should be kept clean and as nearly sterile as possible.

The Effect of Composition of the Fruit upon the Balling of Syrup Used.—Very sour fruit requires more sugar *i.e.*, a more concentrated syrup, than fruit of the same variety of lower acid content, in order to produce the same degree of sweetness as judged by taste, and, conversely, over-ripe fruit will require less sugar to produce the same degree of sweetness as judged by taste.

Effect of Fill of Can on Balling Degree of Syrup.—A can in which the fruit is packed tightly will require a more concentrated syrup than a loosely filled can, because of the greater ratio of fruit to syrup. Therefore, it is sometimes necessary in the packing of soft fruit to increase the Balling degree of the syrup so that the cut-out test will be satisfactory. Some commercial canners cut hundreds of cans from their daily production in order to maintain uniform grades.

Syruping Machines.—The first method used commercially for adding syrup to the cans was by means of what is known as the "dip syruper" now no longer used. In this syruping machine the cans were immersed into a tank of syrup and the method was insanitary and wasteful of syrup.

A syruper now in wide use in all fruit canning districts is that of the displacement type. The can is filled automatically to a predetermined level by the device shown in Fig. 16. Automatic syrupers are accurate, are not wasteful of syrup, are sanitary and have great capacity.

A third style of syruping machine, in which the cans are filled by passing beneath streams of syrup, is in use by several of the large canning organizations in California. The excess syrup flows into a reservoir beneath the machine and is returned by a rotary pump.

Brines and Brining.—Most factories use dilute brines of 1 to 2 per cent salt content for vegetables, and ripe olives are canned in brines varying from 2 to 4 per cent salt.

Salt for canning purposes should be 99 per cent sodium chloride, NaCl, and that of lower purity than 98 per cent should not be used. Iron compounds in the salt will cause discoloration of the brine and precipi-

tation in the can and the iron may combine with the tannin of the vegetables to cause blackening. Calcium salts may cause a white precipitate on boiling or sterilizing and a toughening of the product. Bicarbonate of calcium by boiling is transformed into carbonate and is precipitated as such. The presence of excessive amounts of sodium and magnesium sulphates or other sulphates may give a bitter flavor to vegetables.

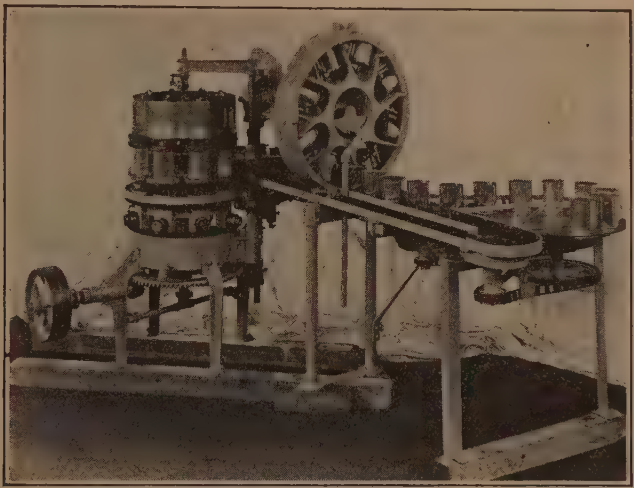

FIG. 16.—Can draining and syruping machine. (*Courtesy, Anderson-Barngrover Mfg. Company*).

For reasons similar to those given for salt, the water for brines should be as pure as possible. The brine should be boiled before use in order to cause coagulation and precipitation of calcium salts and other impurities, and should be allowed to settle or be filtered before use if a heavy precipitate forms.

Hydrometers for Brines.—Two different hydrometers are used in the testing of brines for canning. In the canning of olives, the brine is normally tested by what is known as a "salometer." A brine testing approximately 100 salometer will contain 25 per cent of salt.

The Baumé reading multiplied by 4 corresponds approximately to the salometer reading (see also Table 76). The brine used for corn and peas usually contains a small amount of sugar. The amount of sugar added will vary according to the grade and according to the practice of the cannery, but is usually from 3 to 10 per cent.

Owing to the fact that brine is very much cheaper than syrup, the brining machines are often less perfect in design and operation than the syruping machines and often consist merely of an open pipe from which a stream of brine flows into cans of vegetables or olives passing beneath

on a chain conveyer. The cans are filled to overflowing and the excess of brine is allowed to flow to the sewer. Many factories at the present time, however, are using the automatic displacement type of syruping machine commonly employed in canning fruit.

References

1. Bitting, A. W.: The commercial canning of foods, U. S. Dept. Agr. *Bull.* 196.

CHAPTER IX

EXHAUST AND VACUUM

As employed in the canning industry, "exhausting" usually signifies heating the can and contents before sealing. It may also mean treatment of the container under a mechanically produced vacuum. In either case it has for its purpose the objects listed below.

Objects of Exhausting.—One of the most important objects of exhausting is to remove air from the contents of the can and thereby reduce corrosion of the tin plate, since corrosion is favored by the presence of oxygen.

A second object is to produce a vacuum so that the ends of the can on the grocer's shelf will be concave and thus indicate to the prospective purchaser that it is in sound condition. Convex or bulged ends usually indicate gaseous spoilage.

A third very important purpose of exhausting is to prevent undue strains upon the can during sterilization.

Thorough exhausting by heat tends to prevent overfilling of the can, but also permits a greater fill of soft products, such as berries.

Relation of Temperature of Exhausting to Degree of Vacuum.—A No. 2½ can of fruit or vegetables should, after sterilization and cooling, show a vacuum of 8 to 15 inches when tested with a can vacuum testing gauge. The vacuum will vary according to the temperature of the can at time of sealing. The usual exhausting temperature for fruits is 180 to 205°F., this range of temperature referring to the temperature of the exhaust box. The temperature in the center of the can ordinarily reaches 170 to 180°F. Table 12, showing the relations between the temperature of the can before sealing and the vacuum in the can at room temperature after sterilization, has been compiled and published by Bitting in *Bulletin* 196 of the U. S. Department of Agriculture.

Large cans, such as gallon and No. 10 sizes, if exhausted too thoroughly will become paneled, that is, the sides of the can will be drawn and in certain cases the can may collapse. The No. 3 cans or smaller sizes may be exhausted very thoroughly without danger of collapsing.

Magoon and Culpepper have recently made a study of the relation between the temperatures of the contents of the can and the vacuum in inches after sterilizing and cooling. The authors have calculated the values for the vacuum in inches for a non-contractile receptacle containing air and saturated vapor when sealed at various temperatures and cooled to the uniform temperatures of 0, 10, 20, 30, and 40°C. Their curves will be found in Fig. 17. As the sealing temperature is increased,

TABLE 12.—RELATION BETWEEN TEMPERATURE IN CAN BEFORE SEALING AND VACUUM IN INCHES AFTER STERILIZING AND COOLING

(For solder top cans)

Temperature at time of sealing, degrees F.	Vacuum, in inches
200	16.5
190	15.4
180	13.0
170	10.0
160	8.5
150	8.0
140	7.0
130	5.0
70	1.0

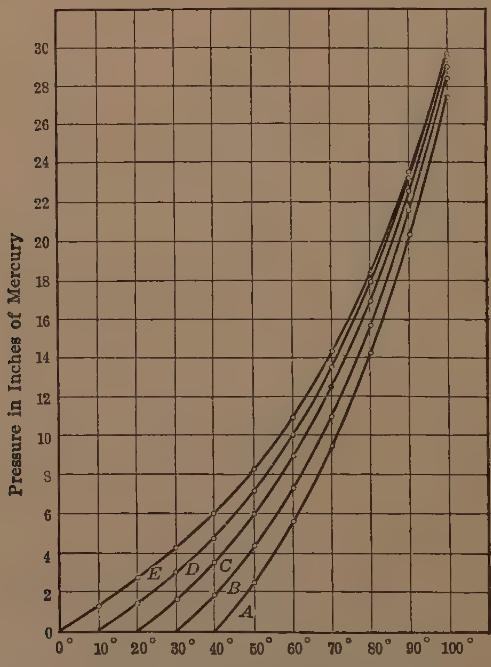

FIG. 17.—Theoretical vacuum curves for a non-contractile can containing air and sufficient water to give saturation when sealed at different uniform temperatures (ranging from 0 to 100°C.) when read at 0, 10, 20, 30 and 40°C. Calculations are based upon mean barometric pressure. Curves for readings made: *A* at 40°C.; *B* at 30°C.; *C* at 20°C.; *D* at 10°C.; *E* at 0°C. (*After Magoon and Culpepper*).

the vacuum in the can increases on cooling. Thus cans sealed at 70 and 50°C. respectively and cooled to 20°C. show about 12.3 and 6 inches vacuum respectively. The curves also show that the temperature of the

can at the time of determining the vacuum markedly affects the vacuum reading. Thus a can sealed at 70°C. should show a vacuum of about 12.3 inches when cooled to 20°C., of about 10.9 inches when cooled at 30°C. and 14.3 inches when cooled to 0°C. This relation explains why cans may leave the cannery in apparently good condition and on storage in a hot climate develop slight internal pressure and the appearance of mild "springers" or spoiled cans. It also explains why cans are more liable to collapse during shipment in cold weather; the low temperature increases the vacuum and hence the atmospheric pressure on the walls of the can.

Cans show less vacuum at high altitudes than at low because of the decrease in barometric pressure as the altitude increases.

Magoon and Culpepper have made an experimental study of the effect of sealing temperature on the vacuum in inches in cans of several important canned foods. They have also determined the effect of processing temperature upon the vacuum. Table 13 gives some of their data on these points.

TABLE 13.—RELATION OF VACUUM TO TEMPERATURE OF SEALING AND PROCESSING TEMPERATURE

(After Magoon and Culpepper)

Product	Temperature of sealing		Temperature of processing		Vacuum inches of mercury
	°C.	°F.	°C.	°F.	
String beans	70	158	100	212.0	12⅛
	70	158	116	240.8	11¾
	70	158	121	249.8	11¾
	80	176	100	212.0	15⅜
	80	176	116	240.8	13¾
	80	176	121	249.8	13 1/16
Corn	70	158	100	212.0	12
	70	158	116	240.8	9⅛
	70	158	121	249.8	9⅞
	80	176	100	212.0	15⅝
	80	176	116	240.8	14⅛
	80	176	121	249.8	13¾
	45–50	...	100	212.0	3
	55–60	...	100	212.0	7.6
	65–70	...	100	212.0	11
	75–80	...	100	212.0	14.6
	95–100	...	100	212.0	21.2
Sweet potatoes	70	158	100	212.0	13⅛
	70	158	116	240.8	11
	70	158	121	249.8	10⅝
	80	176	100	212.0	14
	80	176	116	240.8	13½
	80	176	121	249.8	9

The data indicate that the higher the temperature of sterilization the lower the vacuum in the can, a fact probably accounted for by greater evolution of gas at the higher temperatures and greater expansion of the can, two factors tending to reduce the vacuum (expressed in inches of mercury).

Effect of Temperature of Head Space.—The temperature of the head space was found by Magoon and Culpepper to affect the vacuum in a can as shown by Table 14.

TABLE 14.—EFFECT OF TEMPERATURE OF HEAD SPACE ON VACUUM
(*After Magoon and Culpepper*)

Product	Length of exhaust in steam, in minutes	Vacuum in inches, cans sealed at once	Vacuum in inches, head space cooled but solid content not cooled
Tomatoes No. 2 can........	2	15	
	4	16⅞	
	6	17½	
Tomatoes No. 3 can........	2	15	3½
	4	15	6½
	6	16	
	5	....	8

Relation of Exhausting to Corrosion.—The corrosion of tin plate is caused by the action of organic acids, such as citric, malic, tartaric, acetic or lactic, according to the nature of the product, in the presence of oxygen. H. L. Huenick and others have proved that the tissue of fruit contains a large quantity of air and that unless this air is quite effectively removed by thorough exhausting, corrosion and even pinholing of the plate will follow. It has been shown by Bitting and others that the air is more completely removed by a long exhaust at a moderate temperature than by a short exhaust at a high temperature. In other words, most authorities recommend an exhaust for fruits from 10 to 15 minutes at 160 to 170°F. rather than one of 4 to 6 minutes at 200°F. The relation of exhausting to pinholing will be more fully discussed under the chapter on the spoilage of canned goods.

Types of Exhaust Boxes.—In the exhausting of fruits the cans and contents are ordinarily exposed to the temperature (185 to 205°F.) of the exhaust box for about 4 to 8 minutes; in most cases 6 minutes. A long exhaust at a moderate temperature is to be preferred to a short exhaust at a high temperature.

Disc Exhaust Box.—The disc exhaust box consists of a rectangular metal box in which are several rows of large metal discs from 15 to 18 inches in diameter fitted with cog gears which mesh together. Above the discs are curved iron rods which guide the cans through the exhaust box (see Fig. 18). The cans travel down one row of discs and back the next. Usually the exhaust box contains three to four rows of discs. The number of rows, however, and the length of the exhaust box vary according to the capacity desired and the nature of the product to be exhausted.

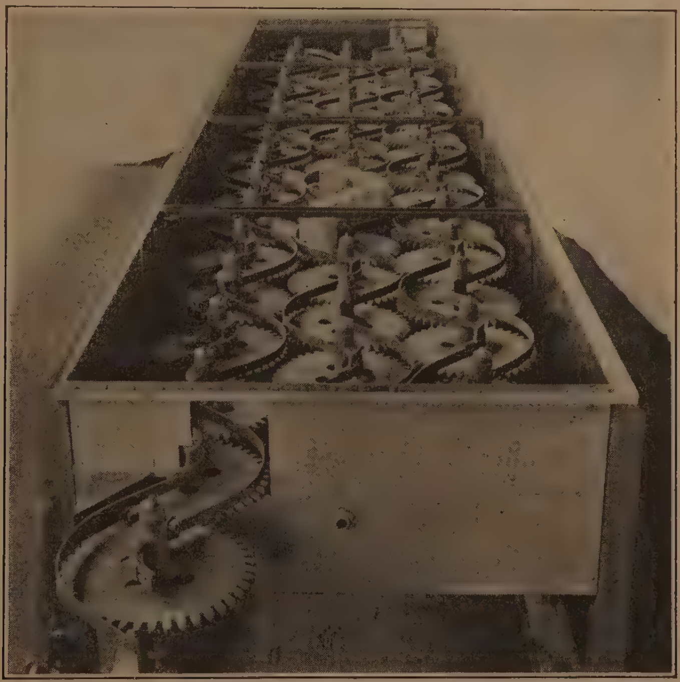

Fig. 18.—Hawkins exhaust box with lid removed to show method of conveying cans. (*Courtesy, Anderson-Barngrover Mfg. Company*).

Cable Exhaust Box.—This is the simplest type of exhaust box and consists of a narrow shallow rectangular metal container through which passes a steel cable which carries the cans.

Chain Exhaust Box.—In one modification of the cable exhaust box the cable is replaced by a chain conveyor. One of the objections to the chain or cable exhaust box is that the cans sometimes become jammed, causing delay and inconvenience.

A rotary exhaust box, in which the cans are carried through a steam-filled cylinder on a reel, has recently been developed.

Circular Exhaust Box.—Where floor space is limited the circular exhaust box in which the cans follow a circular or spiral path in passing through the box, is very desirable.

Exhausting by Mechanical Vacuum.—Practically all food products that are sterilized in glass jars are exhausted under a mechanically produced vacuum instead of by heat, and this process has been applied to the canning of coffee in cans, to the exhausting of canned fish and fish products and to preserves, jellies etc., in glass.

Filling Cans with Precooked Product.—In the canning of corn it is customary to cook the product with a small amount of sugar and seal the corn hot before processing. Exhausting in this case is unnecessary. The same is usually true of peas, pumpkin and sweet potatoes.

Wiegand, of the Oregon Agricultural College, has recently proved that the same process may be used to advantage in the canning of cider. Some tomato products, such as tomato puree and tomato ketchup, are often canned hot and sealed without exhausting.

Exhausting of Solder Top Cans.—The solder top can is rapidly going out of existence, in so far as its commercial use for fruits and vegetables is concerned, but is still used commercially for some fish and meat products and on a small scale in the home canning of foods.

It is customary to fill the container with the prepared product in brine or syrup and seal the lid to the can with solder, a small vent hole in the center of the lid being left open. The can is then passed through steam in the exhaust box, or otherwise heated, after which the vent hole is closed with a small drop of solder.

RELATION OF EXHAUSTING TEMPERATURE TO PRESSURE IN CAN DURING PROCESSING

It has long been recognized by canners that cans are subjected to internal pressure because of the expansion of gases and vapors in the can during sterilization, and that this pressure is greater when the cans are sealed at relatively low temperatures than when sealed at relatively high temperatures. The relation between the temperature of the contents of the can at the time of sealing and the pressure developed in the sealed can during sterilization at various temperatures has been studied quantitatively by Magoon and Culpepper.

Theoretical Values for Water and Air.—The authors have calculated the theoretical values for pressures developed in non-expansible containers filled with air and sufficient water to give saturation, when sealed at various temperatures and processed at 100, 109, 116 and 121°C. (212, 228.2, 240.8 and 249.8°F.) respectively. Their data show that cans sealed at low temperatures develop very high pressure during sterilization and that as a sealing temperature of 100°C. (212°F.) is approached, the pressure developed during sterilization decreases more rapidly than the increase in the temperature of sealing. The pressure increases with the temperature of processing. A can sealed at 80°C. (176°F.) develops

about 14 pounds pressure at 109°C. (228.2°F.), about 22.3 pounds at 116°C. (240.8°F.) and about 26.5 pounds pressure at 121°C. (249.8°F.). A can sealed at 50°C. (122°F.) develops at 100°C. (212°F.) about 14.7 pounds and at 121°C. (249.8°F.) about 30.7 pounds pressure.

Experimental Values for Water and Air.—In determining the experimental values for water in No. 2 cans, Magoon and Culpepper found that: (1) The pressures developed were always below the theoretical; (2) the higher the retort temperature the greater the variation from the theoretical pressures; (3) the higher the initial temperature, the nearer the theoretical does the pressure during sterilizing come; (4) larger cans show a somewhat greater divergence from the theoretical than the smaller cans; and (5) the smaller the head space the lower the pressure obtained.

The rapid rise noted during the first few minutes of heating is due to expansion of the air in the can.

Increase in Volume of Can and "Buckling."—The increase in volume of the can varies with its internal pressure. Large cans sometimes buckle (that is, become permanently distorted along the head seam) from excessive internal pressure.

Increase in volume of the container causes decrease in pressure, a fact which explains some of the deviation of experimental curves from the theoretical and the sudden drops in pressure shown by some of the experimental curves of Magoon and Culpepper. They have found that the can may increase in volume 5 per cent or more under normal canning operations.

According to Bitting an internal pressure of 30 pounds or more is required to buckle a No. 2 can, about 20 pounds for Nos. 2½ and 3 cans and about 10 pounds for No. 10 cans.

Strain on Can.—The actual strain on the can during processing can be obtained by subtracting the retort pressure from the pressure in the can. Thus, if the retort is operated at 10 pounds steam pressure and the pressure in the can is 18 pounds per square inch, the effective pressure or actual strain on the can is 18 minus 10, or 8 pounds per square inch.

When the steam is turned off, the retort pressure rapidly drops to zero. The can does not cool so rapidly as the retort, and consequently it may remain at or near the original temperature and pressure for a short time. It is for this reason that large cans are often cooled under air pressure in the retort to avoid buckling.

Glass Containers.—During processing most glass containers are not hermetically sealed, or are so sealed that slight internal pressure will raise the lids; consequently, the jars are not subjected to internal pressure, or at most to only very slight pressure. One type of glass container is, however, hermetically sealed. The containers of this type are usually filled hot and in addition are exhausted under a mechanical vacuum before sealing in order to reduce internal pressure to a minimum. During steril-

ization in steam retorts, air pressure is applied to hold the caps in place.

Glass containers sealed hot and allowed to cool develop approximately the theoretical vacuum because of the fact that the walls of the glass containers do not contract or expand appreciably, as do those of tin containers.

References

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2. BITTING, A. W.: Exhaust and vacuum, *Nat. Canners' Research Lab., Bull.* 8.
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CHAPTER X

STERILIZATION OF CANNED FRUITS AND VEGETABLES

"Processing," that is, sterilization of canned foods, is the most important operation in canning. Its purposes are: (1) to render the product sterile, and (2) to improve the texture, flavor and appearance by cooking. Sterilization is the more important object. Although sterilization should be thorough enough to insure good keeping quality, it is desirable with many canned fruits and vegetables that this object be accomplished in as short a period as possible in order that the product will not be overcooked and thereby injured in flavor and texture. Because of many serious losses of canned fruits and vegetables in the past through insufficient sterilization, canners at the present time are inclined to oversterilize rather than understerilize their products.

PRINCIPLES OF PROCESSING

The fundamental principles of sterilization have recently been very thoroughly investigated in the Research Laboratory of the National Canners' Association at Washington, D. C. under the direction of W. D. Bigelow, by Magoon and Culpepper in the Bureau of Plant Industry of the U. S. Department of Agriculture, by Dickson of Stanford Medical School, Meyer of the California Medical School, Thompson of Iowa, Rosenau of Harvard and others.

Time and Temperature.—In the sterilization of canned foods both time and temperature are important, since as the temperature of sterilization increases, the sterilizing effect is rapidly increased: thus sterilization at 250°F. is approximately 100 times as rapid as at 212°F. Therefore, in specifying sterilizing temperatures for different products it is essential to specify the time also.

Effect of Condition of Raw Material on Sterilizing.—The experience of canners has proved that fruits or vegetables which contain a large per cent of moldy or otherwise decomposing raw material are very much more difficult to sterilize than the same products in a sound condition. Over-ripe fruit, because of the fact that it softens and forms a compact mass in the can and retards heat penetration, is more difficult to sterilize than fruit of firmer texture, which retains its normal shape and texture. The blanching of fruits or vegetables in boiling water or steam before canning removes some of the microorganisms from the surface of the raw products and in this way reduces their tendency to spoil. It has been proved,

however, that blanching of vegetables does not materially reduce the death temperature of resistant spore-bearing organisms, and it is probable that its principal benefit, as it affects sterilization, lies in removal of some of the microorganisms rather than in any sterilizing effect.

Modes of Heat Transference.—Heat is transferred from the sterilizer to the canned product by two important means, *viz.*, by conduction and by convection. The conduction of heat may be described as the transfer of heat between adjacent molecules.

There are wide variations in the conductivity of various materials. Iron, for example, is known as a good conductor, and when one end of an iron rod is held in a flame the opposite end will, in time, rise in temperature. Wood is known as a very poor conductor.

The transfer of heat in products containing syrup or brine is principally by convection, or transfer of heat by currents set up in the liquid. Heated liquids tend to expand, thereby decreasing in density, a condition which causes them to rise.

Transfer of heat by conduction is very much slower than by convection. Therefore, pasty or semi-solid products, in which convection currents are very sluggish or absent, require very long periods of sterilization. Examples are corn, pumpkin and sweet potatoes. Products, on the other hand, which are suspended in brine or syrup, heat very rapidly, and, other conditions being equal, require a very much shorter period of sterilization than semi-solid products. Examples of canned foods in which convection is the principal means of heat transfer are all varieties of fruits, canned peas and string beans.

Typical Heat Penetration Curve.—The rate of heat penetration in canning is determined by the temperature at the center of the can. If a thermometer is inserted in the center of the can of food and the can supported in a sterilizer which is at constant temperature, three distinct periods will be noted. During the first stage of the heating process the center of the can rises in temperature very slowly, in spite of the fact that during this interval heat units are entering the can at a much higher rate than later in the sterilizing process. During the first stage the material near the outside of the can, however, absorbs, nearly all of the heat which enters the can and the heat, therefore, does not reach the center of the can. During the second period the contents of the can near the sides and ends have reached a high temperature and the temperature at the center of the can rises very rapidly. In the third stage of the heating process the contents of the whole can have approached the temperature of the sterilizer, the temperature gradient has become very low and heat enters the can slowly. These conditions are shown graphically in Fig. 19.

Temperature-measuring Devices.—Nearly all commercially operated steam pressure retorts are equipped with automatic temperature-recording thermometers. This style of thermometer ordinarily consists of a

long, mercury-filled metallic tube at one end of which is a bulb inserted into the retort and at the other end of which are a dial and ink-filled stylus.

The "telltale" thermometer is very generally used by canners. It consists of a small maximum thermometer which operates in the same manner as a clinical thermometer. It is generally attached to a removal screw cap and is protected by a metal sheath. Readings obtained by this

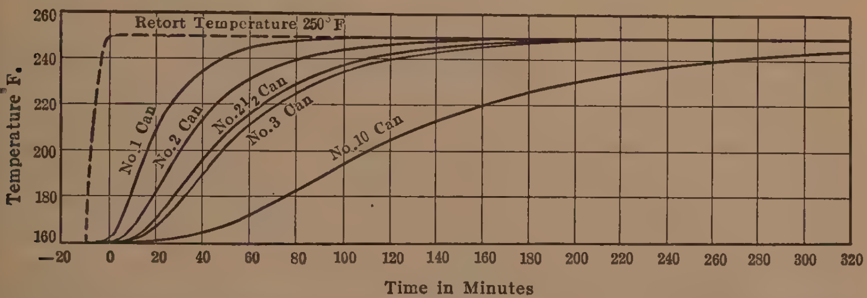

FIG. 19.—Theoretical minimum heat penetration curves for cans of various sizes. (*After Bigelow*).

style of thermometer are likely to be very inaccurate, since the metal cap and sheath conduct heat rapidly. A more satisfactory method of using the telltale thermometer is to attach it to a small piece of wood in such a manner that the bulb of the thermometer rests in the center of the can. Cans containing telltale thermometers may be placed at various points in the sterilizer and a fairly accurate comparison of the temperatures obtained. The can, however, must be removed for reading the thermometers.

A more convenient temperature-recording device is the thermocouple, which is made of very small copper and constantin wires soldered together. The differences in potential generated at the point of contact with the two metals vary with the temperature. The opposite ends of the wires are kept at a constant temperature by immersion in a mixture of ice and water at 0°C., or a compensating potentiometer is used.

The electromotive force developed is measured by a potentiometer which can be calibrated by immersing the thermocouple in water at a known temperature, *e.g.*, in boiling water. This method of determining the rate of heat penetration in canned goods has been highly developed by Bigelow, Director of the National Canners' Research Laboratory. With the set of thermocouples used by him it is possible to determine the temperature of cans in an experimental agitating cooker or in commercial sterilizers in which the cans are not agitated. As many as 10 cans may be tested simultaneously with this outfit. For the ordinary commercial cannery, however, the telltale thermometer is sufficiently accurate.

Magoon and Culpepper[2] make the point that the thermocouple is not an accurate heat-measuring device, because of the high conductivity of the wires as compared with the conductivity of most foods. They state further that a glass thermometer is to be preferred to the thermocouple because of the low heat conductivity of glass. It is probable, however, that the small wires used in the thermocouple are at approximately the same temperature as the canned food with which they are in immediate contact and that little heat is conducted by the wires themselves to the junction of the two metals.

Experimental Retorts.—Magoon and Culpepper used a small retort described by them in Bulletin 956, U. S. Department of Agriculture, 1922. This retort has proved very useful in obtaining fundamental data on heat penetration. Owing to the small size of the retort, equilibrium at any steam pressure desired may be obtained in 10 to 30 seconds. The retort is fitted with a glass thermometer. The top of the mercury column is always in sight and the temperature at the center of the container may be read directly at any time.

Bigelow[1] and his associates have used a small retort in which it is possible to measure the heat penetration by means of a thermocouple in a can that is rotated during heating. It is described fully in Bulletin L-16 of the National Canners' Research Laboratory, 1921.

The Effect of Composition of Container on the Rate of Heat Penetration.—The two materials used for containers in the canning of foods are tin plate and glass. Glass is a poorer conductor than iron, the principal constituent of tin plate. Water, the principal constituent of fruits and vegetables, is a poor conductor of heat, although where convection currents are possible, it heats very rapidly by convection. If convection currents are prevented, as is the case in pasty products, such as corn, or semi-solid products, such as pumpkin, heat penetration is extremely slow and approaches the theoretical minimum penetration for water (see Fig. 19).

The conducting power of any product may be expressed in terms of "diffusivity" which may be defined as the *temperature change produced in a unit cube of material in a unit time by a unit quantity of heat conducted across a unit area of the product per unit difference in temperature.* Diffusivity is constant for any given material.

The diffusivity constant for glass is 0.37, for water 0.084 and for iron 10.8. From this it can be seen that the rate of heat conductance through glass is about one-thirtieth as rapid as through iron or tin plate, but 4.4 times as rapid as through water.

Iron or tin plate transfers heat by conductance 120 times as rapidly as water. This fact explains the very slow heat conductance of corn, pumpkin and sweet potatoes, which are essentially water in composition but of such consistency that convection currents are eliminated. Where

convection currents are active, iron will heat only 4 to 8 times as rapidly as water, and under similar conditions water in a glass container will heat approximately as rapidly as the glass of the container.

Bigelow[1] found that in tin, olives reached the temperature of the retort in approximately 10 minutes; in glass, the time required was approximately 20 minutes. In the sterilization of foods, therefore, it is necessary to take into account the slower penetration of heat in glass than in tin.

Effect of Sugar and Salt on Heat Penetration.—Salt, sugar and other crystaloids in dilute solution do not greatly affect the rate of heat penetration. The retarding effect of the salt concentration in the brines normally used in canning is so small as to be negligible. Very heavy sugar syrups, however, may appreciably slow up heat penetration as was proved by Bigelow's investigations[1] in which the center of the can reached the temperature of the retort in about 6 minutes, where the product was canned in water. In a 50° Balling syrup, 24 minutes were required for the center of the can to reach the temperature of the retort. In a syrup of 10° Balling, approximately 7 minutes, and in a 20° Balling syrup approximately 9 minutes, were required.

It is probable that the dissolved sugar increases the viscosity of the liquid and thereby retards convection currents. The retarding effect, however, is not serious, and is probably partially compensated for by the lowering of the death temperature of spores and molds in syrups of high density.

Effects of Colloids on Heat Penetration.—It has long been observed that starchy food, such as corn, conducts heat very slowly, and experiments by Bigelow, Magoon and Culpepper and others have proved that starch is the retarding agent. Bigelow found that the rate of penetration was retarded in proportion to the concentration of starch in solution until a concentration of 6 per cent was reached. Concentrations of starch in excess of 6 per cent had approximately the same retarding effect as the 6 per cent solution. At 6 per cent concentration of starch, the rate of heat penetration approaches very closely the theoretical rate of heat penetration for pure water, where convection currents are eliminated. This undoubtedly explains the observed fact that concentrations of starch in excess of 6 per cent have approximately the same retarding effect on heat penetration as the 6 per cent solution.

The Effect of Consistency on Heat Penetration.—A tightly packed can of fruit or of vegetables heats very much more slowly than a loosely packed can. For example, it was shown by Bigelow that a No. 3 can of spinach reached the temperature of the retort in 6 minutes at 220°F. where the can contained only 18 ounces of spinach, and that 46 minutes were required where the can contained 27 ounces of spinach.

In commercial products it is customary to pack blanched spinach into the cans very compactly. Pumpkin and sweet potatoes are also packed in cans in practically a solid condition.

Effect of Size of Container.—A longer period of sterilization is required for a No. 10 can of food than for a No. 1 can, for the reason that the distance from the surface of a larger can to the center is greater than in the smaller container and because the ratio of surface to volume is larger in the smaller container.

A No. 1 can contains 11½ fluid ounces and its surface is 45 square inches. The ratio of surface to volume, $\frac{s}{v}$ equals 3.9. A No. 10 can contains 107 fluid ounces, has 175 square inches of surface and $\frac{s}{v}$ equals 1.6. It can, therefore, be seen that the smaller can has a much larger surface exposed per cubic inch of volume. Bigelow and Thompson have determined the effect of the size of the container on the rate of heat penetration and have published tables of factors which show the relative rates of penetration. These factors, however, apply only to cases in which convection currents are not active; for example, in the sterilization of corn, sweet potatoes and pumpkin, tightly packed spinach, etc.

The time required for heat to penetrate to the centers of cans of similar form, but of different size, varies approximately with the square of the radii. Thus, if it requires 60 minutes for the center of a No. 2 can of corn to heat to 240°F. and the time required for a No. 10 can is desired, the following relations would hold:

$$r \text{ No. } 2 = 1.72 \text{ inches wide} \quad (r \text{ No. } 2)^2 = 2.96$$
$$r \text{ No. } 10 = 3.1 \text{ inches wide} \quad (r \text{ No. } 10)^2 = 9.6$$

The time required for the center of the No. 10 can to reach 240°F. is then obtained by use of the formula $\frac{(r_{10})^2}{(r_2)^2} \times t_2$ that is, by the calculation $\frac{9.6}{2.96} \times 60 = 194$ minutes.

Table 15 gives the factors for relative rates of heat penetration of the more common sizes of sanitary cases.

Influence of Rotation.—It has been proved in commercial practice that agitating cookers are much more effective than cookers in which the cans are not agitated during sterilization. Rotation or agitation of the cans mixes the contents and sets up currents which rapidly transfer the heat. Rotation, therefore, is a great aid to heat penetration in products which are packed in syrup or brine, or which are more or less fluid in character. It is not, however, of so great a benefit in the sterilization of solid-packed products, such as sweet potatoes.

Most of the open sterilizers now used in the commercial canning of fruits are of the agitating type, the cans rotating approximately 11

revolutions per minute. This rate of rotation is satisfactory for products consisting of large pieces, such as fruits and tomatoes. As the can rotates the large halves of peaches or large pieces of tomatoes fall through the liquid and set up currents.

TABLE 15.—HEAT PENETRATION FACTORS FOR VARIOUS SIZES OF CANS
(*After Bigelow*)

Size of can	Factor for determining approximate time for cans of specified size				
	No. 1	No. 2	No. 2½	No. 3	No. 10
No. 1	1.00	1.70	2.30	2.50	5.4
No. 2	0.60	1.00	1.40	1.50	3.2
No. 2½	0.44	0.74	1.00	1.10	2.4
No. 3	0.41	0.68	0.90	1.00	2.2
No. 10	0.19	0.31	0.42	0.46	1.0

For products of small size, such as peas and corn, the rate of rotation must be greater in order that the contents of the can be set in rapid motion. This fact is shown in a very striking manner in one of Bigelow's[1] experiments in which it required more than 90 minutes for a can of corn to reach the temperature of the retort when the can was not rotated,

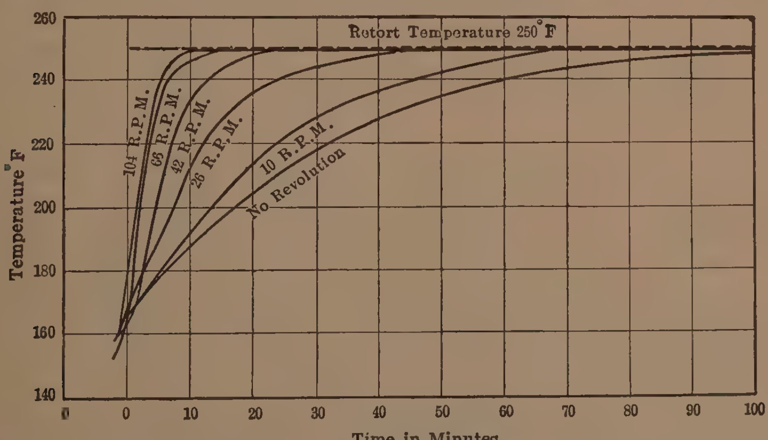

FIG. 20.—Effect of speed of rotation on heat penetration in canned corn. (*After Bigelow*).

70 minutes, at 10 revolutions per minute, about 50 minutes, at 26 revolutions per minute, about 15 minutes, at 66 revolutions per minute, and about 10 minutes, at 110 revolutions per minute. It has been found that rotation of the can permits the use of very much higher temperatures for such products as corn (see Fig. 20).

The discontinuous agitating retort has long been used in the sterilizing of canned milk, where it is necessary to keep a can in motion to prevent scorching of the contents. Several canning machinery companies are at the present time experimenting with continuous agitating pressure sterilizers and at least one of these companies has succeeded in producing a satisfactory machine. It is believed that it will greatly shorten and simplify the sterilization of canned vegetables.

Effect of Initial Temperature of the Contents of the Container.—The time required for the center of the can to reach the temperature of the retort is markedly affected by the temperature of the contents of the can at the beginning of sterilization. For example, if a can of corn is placed in the retort at 70°F. and another is heated to 160°F. before it enters the retort, it will be found that, with the retort operated at 240°F., the first can will reach the temperature of the retort at the end of 80 minutes, whereas the can which entered at 160°F. will reach the temperature of the retort in about 40 minutes. Therefore the center of the first can will receive practically no sterilization at 240°F., whereas that of the second can will receive a sterilization of 40 minutes at 240°. This fact is of very great practical importance in the sterilization of products which conduct heat slowly.

Thorough exhaustion of the can and contents in steam or the packing of the product in the cans hot is a very material aid to the sterilization of canned foods that conduct heat poorly. If the time required for a can heated to certain temperature before entering the retort is known, the rate of heat penetration in a similar can heated to a different temperature before entering the retort can be calculated. The following example will make this point clearer.

Given a retort operated at 240°F. Can No. 1 enters the retort at 184°F. and reaches a temperature of 226°F. in 60 minutes. A second can enters the retort at 90°F. Theoretically, both cans will reach the temperature of the retort, of 240°F., in the same time. The difference in temperature between can No. 1 and the retort temperature is 56°F.; between can No. 2 and the retort, 150°F. The rate of heat penetration in the two cans will be proportional to the temperature gradient between the sterilizer and the can, or, in other words, the ratio of heat penetration in the two cans will be 56:150. Therefore, in order to reach the retort temperature in the same length of time, can No. 2 must heat $^{150}/_{56}$ times as rapidly as can No. 1. Thus, at the end of 60 minutes if can No. 1 is at 226°F., it is 14°F. below the temperature of the retort. Can No. 2, therefore, will be, at the end of the same period of time, $^{150}/_{56}$ times 14° below the retort temperature, or 37.5°F. below the retort temperature; or can No. 2 at the end of 60 minutes will be at a temperature of 202.5°F. if can No. 1 has reached 226°F.

Bigelow has experimentally checked similar calculations and finds them to hold for products which conduct heat slowly.

Effect of Temperature of Sterilizer.—The higher the retort temperature the more rapid the rate of heat penetration, because of the greater temperature gradient between retort and can. Theoretically, a can of corn in a retort at 120°F. will reach the temperature of the retort in the same length of time as a can in a retort at any other temperature, for example, 250°F. In other words, the time required for the can to reach the final retort temperature will be the same regardless of the retort temperature. However, the can in the retort at 250°F. will reach a temperature of 240°F. in a very much shorter time than a can in the retort held at 240°F. Similar considerations hold for other temperatures.

Influence of Cooling on Sterilization.—The rate of cooling after sterilization affects the sterilization of canned foods. A can of food which is cooled quickly to room temperature after sterilization will require a longer period of processing, other things being equal, than a can cooled slowly, because of the longer period at a sterilizing temperature of the unsealed can.

The increase in temperature during sterilization and cooling after sterilization are governed by the same physical laws. During heating the heat travels from the outside inward and is carried by conduction or convection or both. In cooling, the same modes of heat transfer are active, but the heat is traveling outward. Theoretically, if a can of food is processed until retort temperature is reached and is transferred to water maintained at the initial temperature of the can, the temperature will follow a curve which is exactly the reverse of the heating curve.

Air cooling is much slower than water cooling because of the lower heat-carrying capacity of air.

Comparative Value of Steam and Water as Heating Medium.—Some canners contend that water is a much more effective heating medium than live steam. However, cans in live steam are soon covered with a film of water and this film is probably as effective as a larger volume of water in conducting heat to the can.

Bigelow[1] and his associates have made numerous experiments to determine the relative heating value of steam and water and concluded that both are equally effective, provided the source of steam is adequate.

Heat Penetration in Different Products.—Heat penetration in individual products, such as fruits, corn, etc., will be noted in the discussions of the canning of these individual products, see Chapters XI and XIII.

THE EFFECT OF HYDROGEN ION CONCENTRATION ON THE STERILIZATION OF FRUITS AND VEGETABLES

It has long been recognized that acid fruits are very much more easily sterilized than most vegetables. Heating for 10 minutes at 75°C. is

sufficient to sterilize plums or apricots, whereas peas and string beans require at least 4 hours at the boiling point of water, 212°F., for complete sterilization. The most significant difference in composition between these products, as it affects sterilization, is in the acidity.

The work of Bigelow[3] of the National Canners' Association and others has shown that the total acidity of the product determined by titration is not a reliable measure of the effect of the acidity on the sterilization time and temperature, but that the hydrogen ion concentration is a much better criterion upon which to base the relative time and temperature of sterilization of different materials.

Bigelow and Cathcart have determined the hydrogen ion concentration of many of the more commonly canned foods, by use of the standard hydrogen electrode equipment. A brief discussion of the terms used in describing hydrogen ion concentration may make the discussion of this subject clear.

Discussion of Ionization.—All acids in solution in water, and water itself to a slight extent, dissociate to give hydrogen ions. The chemical formula for water is H_2O, and on dissociation it forms for each molecule of water one hydrogen ion, $\overset{+}{H}$, and one hydroxyl ion, $\overline{OH}$. The plus and minus signs indicate that the hydrogen ion carries a plus charge of electricity and the hydroxyl ion a negative charge.

The sour taste of acids is due to the presence of hydrogen ions and the soapy feel and characteristic taste of solutions of alkalis is caused by the $\overline{OH}$ ions. Water yields equal quantities of hydrogen ions and hydroxyl ions. If there is an excess of hydrogen ions, the solution is acid in reaction; if an excess of hydroxyl ions, alkaline in reaction. Acids as well as alkalis vary in their degree of dissociation. Thus a 1 per cent solution of hydrochloric acid contains a very much higher concentration of hydrogen ions than an equivalent solution of acetic acid, and the hydrochloric acid for this reason is a very much stronger and more active acid than acetic acid. Titration of the two solutions would show them to contain the same total amounts of acid. The hydrogen ion concentration, therefore, may be considered as an intensity factor for the comparison of acids.

Toxicity of Hydrogen Ion.—The hydrogen ion has been termed the most toxic of all substances. If the acid of fruits was completely dissociated, fruits would be extremely poisonous, but fruits and animal and vegetable tissue of all sorts contain buffer substances which prevent the formation of excessive amounts of hydrogen ions. Nevertheless, the concentration of hydrogen ions in most fruits is sufficient to affect the death temperature of microorganisms very materially.

Methods of Expressing Hydrogen Ion Concentration.—Hydrogen ion concentration is expressed in several different ways. Expressed as grams per liter, water contains 0.0000001 grams of hydrogen ions per liter, and gooseberries 0.001 grams per liter. Expressed in powers of 10, these

figures become 1×10^{-7} and 1×10^{-3} respectively. The reciprocals of these quantities are 10,000,000 and 1,000 respectively. The logarithm of the reciprocal of the weight in grams per liter of hydrogen ions is probably the most common means of expressing hydrogen ion concentration. For water it is 7 and for gooseberries 3. This logarithm is called the "PH value." The more acid the substance the lower the PH value becomes.

The following table gives a comparison of the various methods of expressing hydrogen ion concentration for several canned foods which represent a wide range of PH values.

It will be seen from this table that gooseberries have 10,000 times the hydrogen ion concentration of lye hominy. This is the reason why the former are very easily sterilized and the latter very difficult to sterilize.

TABLE 16.—HYDROGEN ION CONCENTRATION OF THE JUICES OF TYPICAL CANNED FOODS

(After Bigelow and Cathcart)

Product	Weight of hydrogen ions in grams per liter expressed		Reciprocal of weight in grams per liter	Logarithm of reciprocal (PH value)
	As decimal	In powers of 10		
1. Gooseberries	0.001	$1. \times 10^{-3}$	1,000	3.0
2. Tomatoes	0.000063	6.3×10^{-5}	15,850	4.2
3. Pumpkin	0.00001	$1. \times 10^{-5}$	100,000	5.0
4. Corn	0.0000005	$5. \times 10^{-7}$	1,955,000	6.3
5. Lye hominy, ripe olives, water	0.0000001	$1. \times 10^{-7}$	10,000,000	7.0

Most fruits have a higher hydrogen ion concentration and most vegetables a lower concentration than tomatoes. Tomatoes are easily sterilized at 100°C. (212°F.). Pimientos also are usually sterilized at the same temperature (212°F.) and have a hydrogen ion concentration slightly lower than that of tomatoes. When, however, a PH value of 5 is approached or exceeded, the product enters the class of materials which normally require sterilization under pressure. The accompanying figure after Bigelow and Cathcart illustrates quite clearly the relative positions of various canned foods in the hydrogen ion concentration scale. In studying the chart it must be borne in mind that *high* PH *value* means *low hydrogen ion* concentration.

Experiments by E. C. Dickson of Stanford University have proved that the death temperature of spores of *Bacillus botulinus* is greatly reduced by the acidification of the medium with organic acids, *e.g.*, citric or acetic acids. Experiments performed by the writer in 1913

proved that peas, string beans, corn and fish inoculated with spores of *Bacillus botulinus* were sterilized perfectly in 1 hour at 100°C. by heating in dilute brine acidified with lemon juice to approximately 0.2 per cent acidity expressed as citric, while the same products not acidified developed a vigorous growth of the organism, even after 3 hours' boiling in sealed containers, and were very toxic to guinea pigs, producing typical symptoms of botulism and death when administered in small doses subcutaneously. The experiments were repeated by a graduate student in the Fruit Products Laboratory at the University of California with similar results. Weiss at the Harvard Medical School has since confirmed these results.

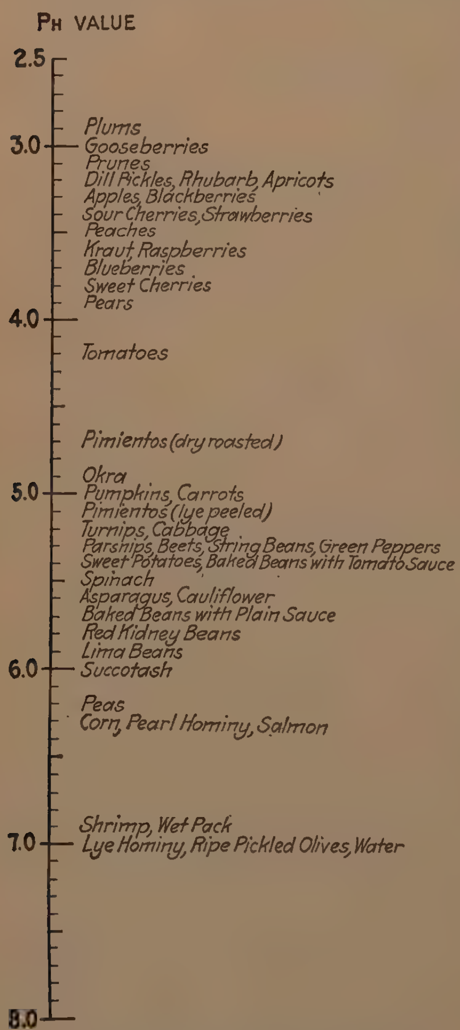

FIG. 21.—PH value of various canned foods. (*After Bigelow and Cathcart*).

Household Application of Acidified Brines in Canning.—The "lemon juice" method of vegetable canning is now in general use in California for the home canning of vegetables. (See Circular 158, University of California Experiment Station, 1915.) For most vegetables canned by this method the brine is acidified with 5 fluid ounces of lemon juice per gallon of brine; that is, this amount of lemon juice is placed in a gallon measure and brine added to make 1 gallon. Some vegetables when canned in this manner possess a slight acid flavor, but this is eliminated if a small "pinch" of baking soda is added when the can is opened and the vegetables placed in a kettle to be cooked. The canned vegetables possess the full fresh vegetable flavor and are superior in flavor to the same materials sterilized under pressure in the usual manner.

STERILIZATION METHODS AND EQUIPMENT

In the first section of this chapter the theory of sterilization was discussed. In the present section the application of these principles to practical canning operations will be described.

Comparison of Fruits and Vegetables.—The nature of the fruit or vegetable to be canned will affect the type of sterilizing equipment to be selected and will determine the temperature and time of sterilization. All fruits, with the exception of olives, are sterilized at 212°F. (100°C.). The acidity of fruits and acid vegetables, such as tomatoes and rhubarb, makes it possible to sterilize them with safety at 212°F. Vegetables, on the other hand, on account of their low acidity and because of their hard texture and the fact that they usually grow in or near the soil and are thus contaminated with spore-bearing organisms, require a much more severe sterilizing process than fruits. Temperatures that would spoil the color, flavor, texture and appearance of fruits in many cases improve the flavor and texture of vegetables. Vegetables, therefore, are usually sterilized at temperatures above 212°F.

Heat Units Required.—Since the specific heat of most fruits and vegetables is practically that of water, the error is small if we assume that the same amount of heat will be required to heat a can of corn or peaches, etc., as is required to heat a similar can of water.

The British thermal unit (B.t.u.) is generally employed in expressing heat quantities commercially and is the amount of heat required to raise the temperature of 1 pound of water 1°F.

Taking a cannery with an output of 70,000 No. 2½ cans of fruit or tomatoes per 10-hour day as an example, the following considerations will indicate the approximate amount of heat required.

Suppose that the average temperature of the tomatoes is 80°F. and that they are to be sterilized at 212°F., or the temperature rise is 132°F. One No. 2½ can of tomatoes or fruit weighs about 2 pounds, or the 70,000 cans will weigh 140,000 pounds. The British thermal units required to bring the product to the sterilizing temperature are $140{,}000 \times 132 =$ 18,480,000 British thermal units, if no heat is lost by radiation. One boiler horsepower = 30 pounds of steam per hour = 33,479 British thermal units per hour. Therefore, for a 10-hour day, 1,848,000 British thermal units per hour or 55.2 boiler horsepowers would be required to heat the cans to 212°F. Normally about 33 per cent additional is required for scalding the fruit or tomatoes or an additional 18 horsepower, making a total minimum of 73.2 horsepower, or about 264 British thermal units per No. 2½ can. To this must be added the heat units lost by radiation and the heat used for heating water and for other purposes.

In commercial fruit canneries in California having a capacity of 150,000 cans per day, the boiler capacity is usually at least 500 horse-

power. This would indicate that the heat losses and use of steam for purposes other than sterilizing are considerable.

The Relation of Steam Pressure to Temperature.—In a closed retort heated with steam the temperature will vary according to the steam pressure. Table 17 shows the relation between steam pressure and temperature.

TABLE 17.—RELATION OF STEAM PRESSURE TO TEMPERATURE OF CANNING RETORT

Pounds pressure per square inch	Temperature in °F.
1	215.2
2	218.3
3	221.3
4	224.2
5	226.9
6	229.5
7	231.9
8	233.3
9	236.6
10	238.8
11	241.0
12	243.0
13	245.3
14	247.3
15	249.1

Effect of Altitude on Sterilization.—For each increase of 500 feet in altitude, the boiling point of water decreases approximately 1°F. The usual recommendation for the sterilization of fruits or vegetables at the boiling point at high altitude is to increase the time of sterilization 2 minutes for each degree Fahrenheit below 212° Altitude does not affect the temperature of a steam retort operating at pressures in excess of atmospheric pressure. The effect of altitude upon the boiling point of water is shown in Table 18.

Increase of Boiling Point by Addition of Salts.—The boiling point of water may be increased by the addition of sodium chloride, calcium chloride or other salts. This fact was made use of in the sterilization of meats and vegetables during the early years of the canning industry. It is possible to obtain a temperature of more than 240°F. by the addition of calcium chloride.

Sterilization in concentrated calcium chloride solution, however, has two objections. First, the cans are subjected to excessive internal pressure and bursting of many may occur, and, secondly, the sterilized cans must be thoroughly washed to remove the adhering solution in order

that corrosion of the tin plate may be prevented. The calcium chloride bath is no longer used commercially in the United States, but may be used on a small scale in cases where it is not feasible or advisable to install steam pressure sterilizers.

TABLE 18.—THE EFFECT OF ALTITUDE UPON THE BOILING POINT OF WATER

Altitude in feet	Boiling point of water	
	°F.	°C. (approx.)
0	212	100
1,025	210	99
2,063	208	98
3,115	206	97
4,169	204	96
5,225	202	94
6,304	200	93
7,381	197	92
8,481	196	91
9,031	195	90

Discontinuous Open Cookers.—Until a few years ago the sterilization of canned fruit and some vegetables was accomplished in open wooden tanks filled with boiling water into which the cans were lowered in crates by means of a crane. This method is still in use in small canneries and in large canneries to a limited extent in the sterilization of small miscellaneous lots of fruit. The water is maintained at the boiling point by open steam jets.

Continuous Non-agitating Open Cooker.—The first improvement on the discontinuous open cooker for the canning of fruits was the continuous non-agitating Dixon cooker which consists of a long wooden tank containing boiling water through which the cans placed, in metal baskets, are carried by an overhead conveyor. It was in common use in California fruit canneries until very recently. The objections to this cooker were: (1) that is was very inefficient in its use of steam and wasted large amounts of heat through the evaporation of water from the sterilizer; (2) that the time of sterilization was difficult to regulate and adjust; (3) that the sterilizer occupied too large a floor space; and (4) it was complicated and costly in operation. The Dixon cooker has been practically wholly replaced by the agitating continuous open cooker.

By the term "open" the commercial canner understands a cooker which operates at atmospheric pressure. The term is somewhat misleading for the reason that the usual cooker is almost completely enclosed. It operates, however, at approximately 212°F. (100°C.).

Continuous Agitating Cookers.—The appearance of a typical continuous agitating cooker may be seen in Fig. 22. The can enters a small

Fig. 22.—Continuous agitating open sterilizer for fruits and tomatoes. (*Courtesy, Anderson-Barngrover Mfg. Company*).

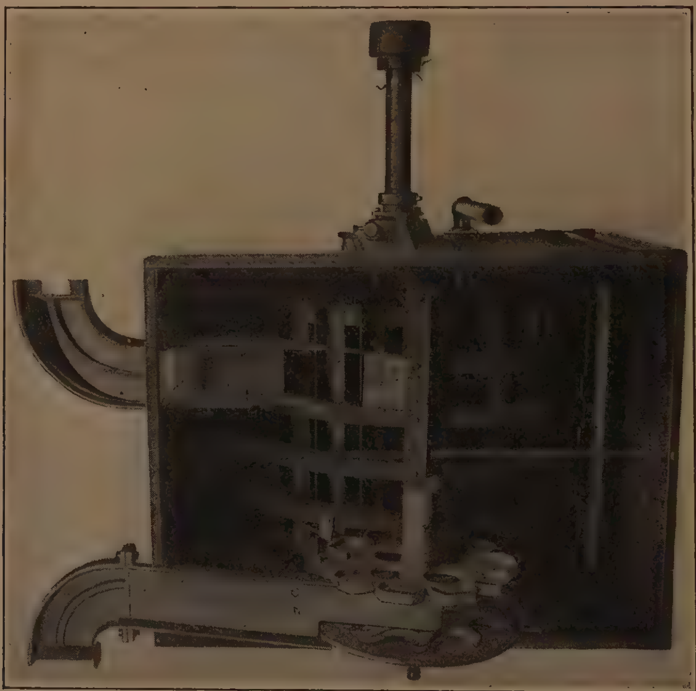

Fig. 23.—Continuous cooler for cans viewed from top to show revolving reel and stationary spiral which convey cans in cooler and in sterilizer. (*Courtesy, Anderson-Barngrover Mfg. Company*).

port hole at one end of the sterilizer and travels along a spiral inside the sterilizer. The method of conveying the cans is shown in Fig. 23.

During its course through the sterilizer it is rolled continuously and is thereby thoroughly agitated.

In several types of continuous agitating cookers the temperature inside the sterilizer is above 212°F., although the sterilizer is open to the atmosphere. The higher temperatures are attained by means of steam pipes placed immediately beneath the conveyors. Temperatures of 215 to 218°F. are often attained in this style of sterilizer. In addition to the radiated heat from the steam pipes the cans are also heated by live steam, which is admitted to the sterilizer. It is claimed that this design of sterilizer is inefficient in its use of steam.

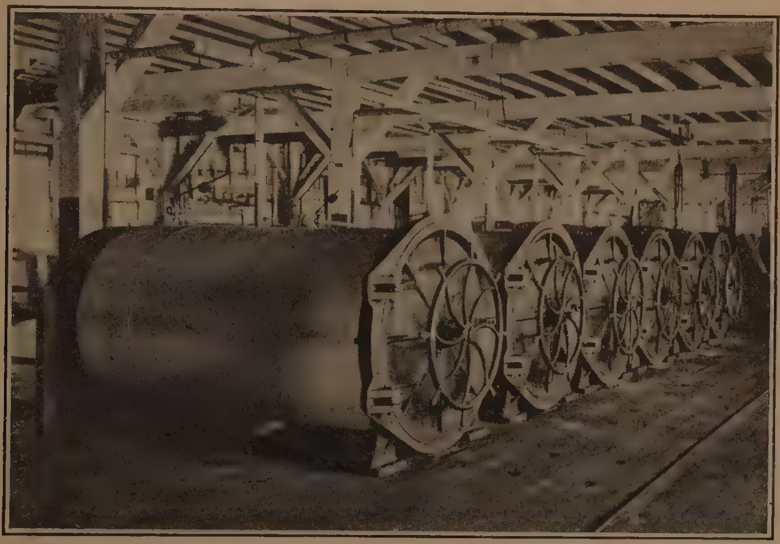

Fig. 24.—Battery of horizontal cylindrical retorts for sterilization of vegetables. (*Courtesy, The Canner*).

The length of time of sterilization in one design of sterilizer is regulated by means of small port holes located at different points on the side of the sterilizer (see Fig. 22). By opening or closing various port holes the cans can be removed at any desired point. Variable speed transmission can also be used to adjust the time. The average agitating continuous cooker has a maximum capacity of more than 25,000 cans per day, but the capacity varies with the length of sterilization.

Discontinuous Non-agitating Pressure Sterilizers.—The simplest form of pressure sterilizer is an upright or horizontal heavy steel cylinder in which the cans are placed in crates and which is operated with steam under pressure. In California the horizontal retort is the more popular and in eastern canneries the small upright retort which is sunk below the floor level is in most common use. The advantage claimed for the horizontal retort is that cans may be placed in crates or small steel

cars which can be quickly and easily placed on a steel track in the retort. Usually both ends of the retort are fitted with heavy swinging doors, so that after sterilization the cars of sterilized cans may be removed from one end of the retort while loaded cars may be entered at the opposite end. The appearance of such a retort is shown in Fig. 24. The usual size is approximately 60 inches by 10 to 20 feet.

The upright retorts are used in a battery above which is a traveling crane, usually operated by steam or air pressure. Cans are filled into circular crates which are lowered into the retorts. It is claimed for this style of retort, that owing to the fact that only a small quantity of material is required to fill it, the exhausted or the sealed cans are not allowed to stand very long without sterilization and hence do not have an opportunity to cool appreciably before sterilization.

In the operation of a retort it is essential that all air be removed before sterilization is undertaken. This is accomplished by opening release valves until the contents of the retort are thoroughly heated by live steam. In order that the cans in the retort shall all be heated to the same temperature, it is essential that the steam be in active circulation. If this is not the case, air pockets will often form in various parts of the retort and sterilization at this particular point will not be accomplished, because of the lower temperature. Circulation is usually accomplished by means of open pet cocks located at various points on the sterilizer. Steam in small volume escapes through these cocks throughout the sterilizing process and thus the circulation of the steam is accomplished. The pet cocks also permit the escape of air which may enter the retort with the steam. Retorts should be insulated with magnesia or asbestos to minimize heat losses.

Automatic Temperature Control.—Owing to fluctuations in the steam pressure in most boilers and to various other factors, such as chilling of the retort by currents of cold air, it is desirable that the retorts be placed under automatic temperature control. Temperature regulators for retorts may be based upon adjustment by steam pressure, in which case the regulator operates on the same principle as a steam reducing valve; or the temperature may be maintained by means of counterbalancing of the steam pressure against air pressure. The latter type of regulator has proved the more satisfactory. Fig. 25 shows the arrangement of a typical automatic temperature control device on a vertical retort.

It is sometimes necessary to use air pressure in the retorts with the steam pressure. This is particularly true in the sterilization of products in glass under pressure, for the reason that the lids of the jars or glass tumblers are loosened by internal steam pressure unless the internal pressure is counterbalanced by outside pressure of air, since the internal pressure in the jar will exceed the steam pressure in the retort. When

the steam is shut off from the retort at the end of the sterilization period it becomes necessary to deliver compressed air to the retort and maintain a pressure in excess of that existing in the containers. Unless air is admitted to the retort to counterbalance the interior pressure of the can, No. 10 and other large cans tend to buckle or burst at the ends from excessive interior pressure after sterilization is complete. When air is used during sterilization, however, it is necessary to provide good

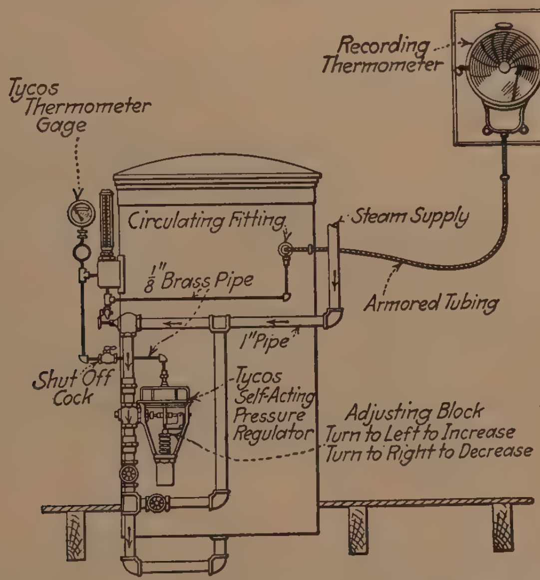

FIG. 25.—Temperature-regulating equipment and recording thermometer on a vertical retort. (*Courtesy, The Taylor Instrument Company*).

circulation in the retort to prevent "pocketing" of the air with consequent lowered temperature. Open pet cocks will accomplish the desired result.

The cans or jars are cooled in the retort by sprays of water or by admitting water to the bottom of the retort. The admission of water to the closed retort causes condensation of the steam, thereby creating a vacuum in the retort. This will also tend to increase the internal pressure of the cans or jars greatly and renders the use of compressed air during cooling doubly desirable.

Agitating Discontinuous Pressure Sterilizers.—This type of sterilizer has been developed in the sterilization of milk. It has been found that milk tends to scorch and curdle unless it is agitated during sterilization under pressure. The cans are placed in a cage inside the retort and the cage revolved during sterilization, keeping the cans constantly in motion and thoroughly agitated. The writer is not aware that this sterilizer is used extensively for other products, although it would be undoubt-

edly of service in the sterilization of some vegetables. The continuous agitating sterilizer shown in Fig. 26 is now being used for canned milk.

Continuous Agitating Pressure Sterilizers.—During the past 2 or 3 years several cannery machinery companies have experimented in the manufacture of continuous agitating sterilizers built on the same general principle as the open agitating cooker. The principal difficulty has been the one of admitting the cans to the retort and removing them after sterilization continuously without affecting the steam pressure in the

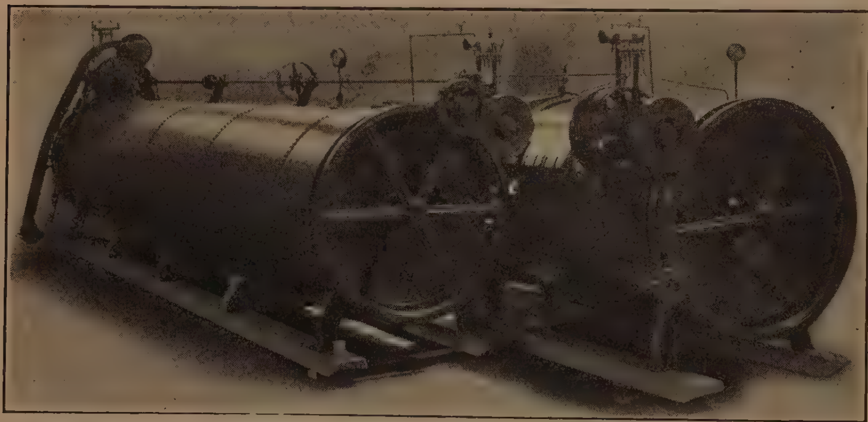

FIG. 26.—Continuous agitating pressure sterilizer (retort) and cooler. (*Courtesy, The Anderson-Barngrover Mfg. Company*).

retort, but this difficulty has been overcome by the construction shown in Fig. 26. It has been proved by Bigelow and others that a very much higher temperature and a correspondingly shorter time can be employed with the agitating continuous cooker, for the reason that agitation prevents overheating of the product in contact with the tin.

Cooling after Sterilization.—As soon as the contents of the can have been thoroughly sterilized it is essential that the can and contents be cooled immediately. It is customary in most canneries to stack the cans in large piles after sterilization, and if the contents of the cans have not previously been cooled sufficiently, cooking may continue for several days in the center of these stacks. This results in the development of dark color in peaches and pears, in the scorching and darkening of tomatoes and other vegetables and in the development of "flat sours" in vegetables through the growth of thermophilic spore-bearing bacteria which survive the usual commercial sterilization process.

The cans should not be cooled to too low a temperature for the reason that they will remain wet and become rusty. A temperature of 110 to 115°F. is high enough to dry the cans but not high enough to cause injury to the contents. Cooling is accomplished by sprays of cold water or by

passing the cans through a tank of running cold water. In either system a large amount of water is needed.

A cooling device of the same general design as the continuous agitating sterilizer is shown in Fig. 23.

The cooling process is completed by stacking the cans over night in an open court, usually in such a manner that air currents may pass freely around the cans.

Testing Vacuum of Cans.—It is desirable that the canner have accurate information upon the degree of vacuum in the cans after sterilizing and cooling because faulty sealing of the cans is very quickly detected by this means. The simplest form of tester consists of a dial gauge equipped with a sharp, hollow tube and large rubber gasket. The sharp tube is inserted in the lid of the can by a sharp blow and the entrance of air prevented by the heavy rubber gasket. The vacuum may then be instantly read from the dial.

The appearance of such a can tester is shown in Cruess and Christie's "Laboratory Manual of Fruit and Vegetable Products." Another excellent vacuum tester consists of a bell jar in which the can is placed under water and which is subjected to a gradually increasing vacuum by means of a hand pump. Poorly sealed cans emit bubbles of air. When the vacuum inside the can and in the bell jar become equal the head of the can bulges slightly. This vacuum tester is valuable in making frequent observations on experimental cans, because the cans are not injured.

Canners also test the cooled cans by tapping with a short steel rod. Imperfectly sealed cans or "leakers" give forth a "hollow" sound and perfectly sealed cans a "flat" sound. The method is simple, extremely rapid and surprisingly delicate. An experienced workman rarely fails to detect faulty cans by this test.

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CHAPTER XI

CANNING OF FRUITS

The commercial canning of fruits has increased rapidly during the past 20 years, particularly on the Pacific Coast of the United States and in Hawaii. Australia also is vigorously developing its fruit canning industry, in some cases under government subsidy and supervision. Very large new plantings of canning fruits have been made in the Pacific Coast States during the past 5 years and the production of certain varieties of canning fruits will double within the next 5 years.

General.—The use of fruit varieties especially suited to canning and the careful observance of established commercial size and quality grades are the two most important fundamentals in the successful commercial canning of fruits. Ungraded canned fruit is unattractive in appearance, uneven in color, texture and maturity and is not a product that will command a high enough price to return a reasonable profit to the canner and the grower.

The fruit must be gathered at the proper stage of maturity for canning, that is, it usually should not be as ripe nor as soft as that for eating fresh, yet it should have attained the flavor characteristic of the ripe fruit.

The fruit should be picked carefully and transported to the cannery quickly, and without bruising.

Boxes must be clean and must not be permitted to become moldy and heavily impregnated with fermented and soured fruit juice or pulp.

A clean factory operated with strict observance of the fundamental principles of sanitation is essential to the production of canned fruits of high quality.

The Canning Season for Fruits and Vegetables in California and Hawaii.—The fruit canning season starts in California with cherries in May and ends with tomatoes in November (see Fig. 6).

PEACHES (*Prunus persica*)

A larger quantity of peaches is canned than of any other single fruit. Its delicate flavor, which persists after canning, its firm texture, which permits sterilization without disintegration, its attractive appearance and moderate price have combined to give the peach its present popularity.

Varieties of Peaches for Canning.—Peaches for canning should be of large size, yellow color, close, tender fiber, not coarse or ragged, and

should have good cooking quality, that is, should retain their form, size, flavor, color and aroma during sterilization in the can. The fruit should ripen evenly from the surface to the pit and should not be softer at the pit than at the surface. Most of the good table varieties are not suitable for commercial canning.

The clingstone varieties used in California for canning most nearly fulfil the above requirements. The more important of these may be described as follows:

The Tuscan or "Tuskena" is a large clingstone variety that ripens in California during the latter part of July and the first week of August. It may be distinguished from the Phillips Cling by the pink color of its flesh near the pit. It is somewhat more tender than the Phillips Cling but is equal to it in flavor and is a good canning variety.

The Phillips Cling, which is yellow and has no pink color around the pit, ripens late in August and early in September and is usually somewhat larger and firmer than the Tuscan. The Phillips Cling ripens over a longer period than the Tuscan and is the most important canning peach in California.

The Orange Cling, a very large peach, of deep yellow color and with considerable pink blush on the skin, ripens between the seasons of the Tuscan and the Phillips, but is not as important as the Tuscan or Phillips Clings.

The Walton Cling resembles the Phillips Cling in quality and appearance, and is grown in the central Sacramento Valley where it is supposed to have originated. The Haus, Peaks, Sims and Pelora Cling peaches have also proved popular for canning and resemble the Phillips in quality.

Of the freestone peaches used in California for canning purposes the most important is the Muir, which ripens in late July and early August. It is yellow in color, possesses a very free pit, is firmer than the Elberta and usually larger.

The Lovell freestone ripens a few weeks later than the Muir and because it is firmer is considered to be a more desirable peach. It is somewhat lighter yellow in color than the Muir, but of excellent color and is a good canning variety.

The Elberta peach is grown in California primarily for table use. A small quantity of the fruit is canned commercially, but it is not considered desirable for the purpose because of the pink color of the flesh near the pit and because the flesh becomes rough during the lye peeling. The flesh tends to soften badly or become "ragged" during sterilization. It is used rather extensively in the eastern United States for canning purposes.

The Nurserymen's Selection Association of California has recommended that peaches be planted for canning purposes in a ratio of 85 per

cent clingstone, to 15 per cent freestone. They recommend that 40 per cent of the clingstone varieties be Phillips Cling, 25 per cent Tuscan, 10 per cent Sims and 25 per cent of other varieties so chosen that the canning season may be as long as possible. Of the freestone varieties they recommend that 70 per cent be Lovell, 10 per cent Muir, 10 per cent Solway and 10 per cent other varieties.

The shipping varieties of peaches grown in Georgia have not been found suitable for canning purposes except for pie fruit, because the color is not desirable and because the fruit softens badly during canning.

Of the varieties adapted to the eastern United States, the Elberta seems to be the most popular for canning.

Picking and Shipping Peaches for Canning.—Peaches for canning purposes should be picked when of maximum size and at the firm ripe stage of maturity. Great care must be used in order to avoid bruising. The lug boxes should not be overfilled and the ends should be protected by cleats so that the fruit will not be crushed when the boxes are stacked in the car or truck.

It is customary to allow the fruit to stand in the orchard during part of the night to cool before shipment, in order to minimize spoilage in transit. It is necessary to make several pickings of the fruit so that all of it may be gathered at the most desirable stage of maturity.

Delay after picking results in over-ripening and in deterioration of flavor, and if the fruit is to be held several days it should be placed in cold storage at 32 to 36°F.

Receiving.—On receipt at the cannery the fruit should be graded roughly according to maturity and variety by segregation of boxes. The receiving room should be cool and well ventilated.

Door Test.—In most canneries a large sample of each shipment of fruit is carefully sorted to determine the relative amounts of the different grades present, and the grower is paid accordingly. In some canneries two grades known as "1" and "2," or "A" and "B," are made. In others, three or more grades, A, B and C, etc., are recognized. B-grade fruit receives a much lower price than A-grade fruit, usually 50 per cent of the A-grade price. The "door test" is the canners' most powerful inducement to delivery of high-grade fruit.

Cutting and Pitting.—The first operation in the canning process is that of halving and pitting. This work is done by women who stand at long tables.

Tables.—Many different styles of cutting tables are used. One type in use by one of the largest canning organizations in California consists of a long table equipped with a belt which delivers to the cutters the desired amount of fruit, usually one lug box (approximately 50 pounds of fruit) at a time. A second belt beneath the cutting table carries away the pits and culls. In front of each cutter are from two to three dishpans.

In one of these is placed the firm ripe fruit, in another the green fruit and in the third the over-ripe and pie fruit.

In other canneries the fruit is delivered to the cutting tables by hand trucks, but this method of delivery is expensive and often results in confusion. In one large California cannery the cutting tables are equipped with three belts, one to deliver the firm fruit to the peeling machine, one to care for the pie grade of fruit and one to carry away the pits. In small canneries the cutting table is not equipped with belts; and the pits and refuse are thrown into buckets or dishpans, which are periodically removed by the men who deliver the fresh fruit to the cutters.

Cutting.—A fruit cutting knife is used to cut the peach around the suture from the surface to the pit. A spoon-shaped knife is then inserted from the stem end of the peach and with this instrument the flesh is cut from the pit. Freestone varieties are halved and the pit is then easily removed with the cutting knife.

Mechanical devices have been developed recently for pitting and halving peaches, but machines are still in the experimental stage and not in general use.

Trimming.—The women who do the cutting also trim the fruit and do a reasonable amount of sorting for quality. Thus, pie-grade fruit is segregated from the better grades to some extent.

Cutting and pitting of peaches are the most expensive operations in the canning of this fruit. In one large plant in the San Joaquin Valley, 250 cutters were necesary, while only 50 workmen were required for filling the cans and 150 for all other operations. Approximately 90 tons of fruit was canned per 10-hour day with this force of 450 employees. The ratio of cutters to other workmen will vary with the variety and size of the fruit and with the amount of automatic machinery employed.

It is essential that the cutting operations be directed by capable forewomen who are thoroughly familiar with fruit varieties and fruit grades.

Peeling.—In the commercial canneries of peaches lye peeling is almost universally used and very few commercial canneries still use the hand peeling process. The fruit is lye peeled after halving and pitting. Lye-peeling machines have been described in Chapter VI.

The lye solution varies in strength from 1 to 5 per cent sodium hydroxide, and the time of immersion in the boiling lye is from 20 seconds to 2 minutes, depending upon the maturity of the fruit. In some peelers the time is varied; in others, the lye concentration.

Washing.—Following the lye treatment the fruit is thoroughly washed, either under sprays of water or in tanks of running water. The lye must be thoroughly removed from the surface of the fruit to avoid darkening, and no softened tissue must remain in the pit cavity;

otherwise a jelly will form in the cavities and injure the appearance of the canned product.

Blanching.—It has been found advantageous to pass the peeled and washed fruit through a steam blancher for 2 or 3 minutes to destroy the oxidase and thus to prevent browning of the fruit.

Amount of Lye Used.—The amount of lye required varies from about 6 to about 15 pounds per green ton of fruit, according to type of peeling machine and the variety of peaches used. In one large cannery during the 1920 season about 7 pounds of 95 per cent sodium hydroxide were required for each ton of peaches peeled.

Steam Peeling.—Some varieties of peaches, especially thoroughly ripe table varieties, can be peeled by placing the halved and pitted fruit on trays and subjecting the fruit to live steam for several minutes. The peels can then be slipped from the fruit with the fingers.

Loss in Peeling.—The loss in weight of fruit in lye peeling of peaches is approximately 12 per cent according to data obtained upon the spray type of lye peeler. Hand peeling results in a loss of about 20 per cent.

Sorting.—The peeled fruit passes from the lye peeler or blancher to a broad rubber or woven wire belt before which are sorters who remove fruit which is blemished, broken, badly peeled or improperly washed. The fruit in prime condition travels by conveyor to the grading machine, while pie fruit is carried by belt to the canning room and does not pass over the grader. The women at the sorting belt can sort fruit at very much lower cost and very much more efficiently than can those engaged in placing the fruit in the cans.

Grading.—Usually five grades for size are made by means of the grading machines described in Chapter VII. The smallest fruit is usually placed in the pie grade and the largest size is often sliced before canning. The largest and most perfect fruit forms the Fancy grade, while fruit of smaller sizes is represented by Choice, Standard, Second and Pie grades respectively. The Pie grade in addition comprises blemished fruit, over-ripe fruit and green fruit. Most canners consider Fancy-grade peaches as those $^{76}/_{32}$ of an inch or greater in diameter, Choice-grade $^{64}/_{32}$ or above and Standard-grade $^{56}/_{32}$ or above. Second and Pie grades are not graded for size. (See Fig. 12 for appearance of a peach grader.)

Slicing.—There is an increasing demand for sliced peaches for dessert purposes, ordinarily canned in No. 1 tall cans. There is, however, a tendency at the present time to slice a great deal of the pie grade of fruit in order to make it more attractive and more uniform in appearance.

The peach slicing machine consists of several circular revolving knives, beneath and against which the fruit is carried by means of a rubber belt (See Fig. 27). A vibrating screen automatically places most of the halves

cup side down, before slicing but it is also necessary for an attendant to properly invert a small percentage of the halves by hand.

Filling the Cans.—From the cutting machine the peaches pass by means of belts to the canning tables where the women divert the fruit by means of a small gate located at each canning sink. There are as many canning tables as there are grades of peaches, only one grade being canned at each table. The empty cans are carried to the canning tables by grav-

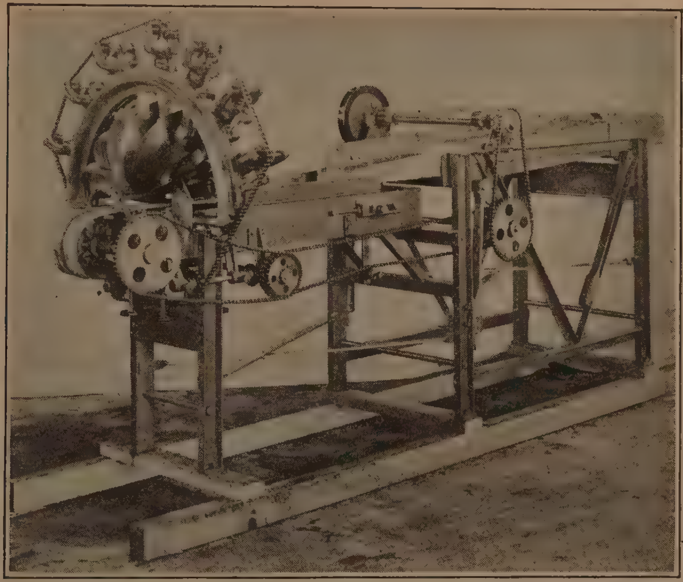

FIG. 27.—Peach slicing machine. (*Courtesy, Anderson-Barngrover Mfg. Company*).

ity conveyors from a can loft above the canning room or by overhead conveyor direct from a railroad car and the filled cans are usually transported from the canning tables to the syruping machines by means of belts.

Inspection.—The fruit is carefully inspected by the women who fill the cans, and blemished or inferior fruit which has escaped the sorters is segregated and sent to the proper table.

Weighing.—The cans are sometimes filled by weight by placing the filled can on a small counterpoised scale. The weight of peaches placed in a No. 2½ can will vary from 19 to 22 ounces. The Government regulations require that a No. 2½ can of peaches contain at least 20 ounces of drained fruit. Great care and considerable skill must be employed in filling the cans in order that they may contain the required amount of fruit without crushing. Some factories fill the cans according to the number of pieces per can rather than by weight.

Darkening.—The time which elapses between grading and canning should be as short as possible so that darkening of the fruit through oxidation shall not take place. Oxidation is reduced by keeping the fruit submerged in water at the canning tables and by sprays of water during the grading operations.

Can Sizes.—Most of the peaches are placed in No. 2½ cans, with the exception of the Pie grade, which usually is canned in No. 10 cans for the use of bakers, hotels and other similar establishments. A limited quantity of the higher grades is also canned in No. 10 cans for hotel trade

Fig. 28.—Filling peaches into cans. (*California Packing Corporation*).

and in No. 2½ flat or No. 1 tall cans for the use of small families, picnickers, etc. Sliced peaches are frequently canned in No. 1 tall cans.

Syruping.—The cans are automatically filled with syrup by syruping machines, described in Chapter VIII (see Fig. 16). The best grade of peaches receives a syrup of 55° Balling and the other grades 40, 25 and 10° Balling and water respectively in most California canneries. Some canneries use syrups richer in sugar than those given above, but none use syrups more dilute than these. Peaches low in sugar should be given syrups of higher Balling degree than recommended by the Canners' League standards. Fancy peaches should test at least 30° Balling on the cut-out test, Choice at least 22° Balling, Standard at least 17° and Second at least 11° Balling.

Exhausting.—The filled cans are carried by automatic conveyors from the syruping machines to the exhaust box, in which they are heated in

live steam at a temperature of 190 to 212°F. for from 5 to 8 minutes. The usual temperature is 200 to 203°F. and the time about 4 to 6 minutes. The first object of exhausting is to expel air from the fruit, the presence of which favors corrosion of the tin plate. The second object is to soften the fruit, so that a larger amount may be placed in the can without crushing.

Exhaust boxes are described in Chapter IX (see also Fig. 18).

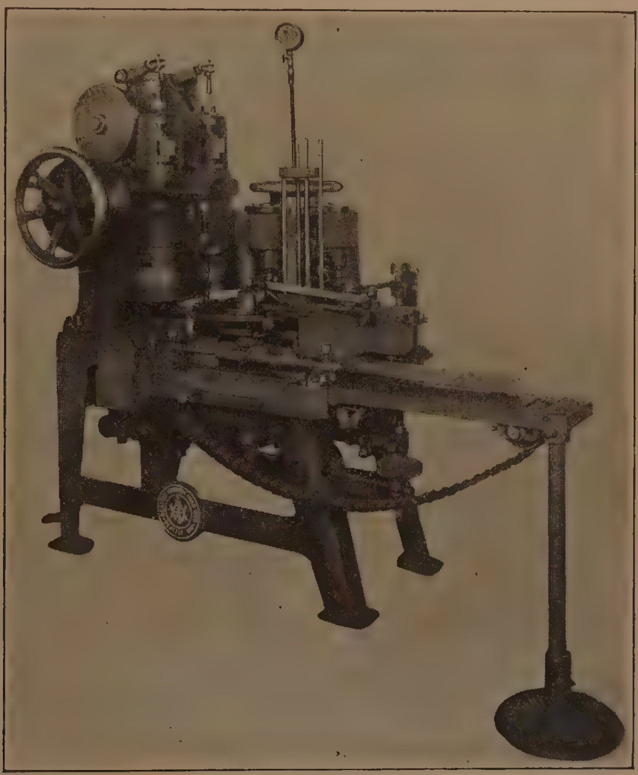

FIG. 29.—Automatic can sealing machine. (*Courtesy, The Seattle Astoria Iron Works*).

It is considered by Bitting[1] that much better results are obtained by exhausting the fruit at a moderate temperature for a relatively long time than by subjecting it to a short exhaust at a very high temperature. Thus, an exhaust at 180°F. for 10 minutes is more satisfactory than a 4 minutes' exhaust at 212°F., for the reason that the high temperature is apt to soften the fruit in the top of the can and will not expel the air from the tissues of the fruit as effectively as exhausting at a lower temperature for a longer time.

Marking the Cans.—Rubber stamps are used to mark the cans or lids with letters or numbers in indelible quick-drying ink to indicate the

variety of fruit, its grade and other data of use to the canner. Many canneries allow the cans to roll through a marking machine after sealing in such a manner that the cans are marked with the number of bands corresponding to the grade. Cans marked with bands can be quickly found in the stacks in the warehouse and are not apt to become mislabeled.

Sealing.—The centers of the cans usually attain a temperature of 140 to 160°F. in the exhaust box and from the exhaust box pass directly to the double-seaming machine, which automatically places the caps on the cans and seals them, at the rate of from 25 to 100 cans per minute. The double-seaming machines must at all times be kept in careful adjustment so that the cans may be perfectly sealed and to prevent loss through leakage and spoilage. More spoilage of canned peaches and other fruits through fermentation is caused by faulty double-seaming than by any other single cause.

Sterilizing.—This is the most important stage in the canning process. It should be thorough enough to cook the fruit sufficiently, but not so prolonged that the fruit is badly softened. The length of sterilization will vary greatly with the maturity and variety. The following table gives the length of sterilization for several varieties of the more important canned peaches.

TABLE 19.—PROCESSING TIMES FOR PEACHES AT 212°F.

Variety and maturity	Size of can, no.	Approximate time at 212°F. in non-agitating cooker, minutes	Approximate time at 212°F. in agitating cooker, minutes
Tuscan Cling, prime ripe	2½	20–25	14½–20
Tuscan Cling, green	2½	25–30	15 –25
Tuscan Cling, prime ripe	10	25–30	
Phillips Cling, prime ripe	2½	35	30 –33
Phillips Cling, green	2½	40	35 –40
Phillips Cling, prime ripe	10	40	35 –40
Muir Freestone, prime ripe	2½	15–20	12
Solid pack pie fruit, all varieties	10	30 @ 240°F.	30 @ 240°F.

Cooling.—Immediately after sterilization the canned fruit should be thoroughly cooled to a temperature where cooking will cease but not low enough to prevent drying of the cans. If the can and contents are cooled to a temperature of 110 to 120°F. drying will take place satisfactorily and rusting will not occur. If the cans are not cooled sufficiently cooking process will continue in the can with the result that the peaches become soft and acquire a dark or pink color.

Testing Cans for Leakage.—As the cans are placed on trays after emerging from the water cooler they are tapped with an iron rod to determine whether the sealing has been satisfactory or not.

The percentage of leaky cans will usually be less than ½ of 1 per cent. Testing of cans should be done as promptly as possible after sterilization so that the faulty operation of the can sealers may be quickly detected in order to permit utilization of the fruit before spoilage occurs. Leaky cans may be opened, recanned as Pie-grade fruit and resterilized.

Storage.—The canned peaches should be stored for several weeks before marketing in order that faulty cans may be detected and to permit equalization of the syrup and fruit. The flavor of the product improves during storage.

The cans are placed on the warehouse floor in stacks approximately 15 to 20 feet high with laths placed between each tier of cans to bind them and to prevent undue strain on the cans at the bottom of the pile.

The warehouse should be cool, dry and well ventilated and the cans must be protected against the accumulation of moisture to prevent rusting.

Cut-out Tests.—A large number of samples of commercially canned peaches have been examined by the National Canners' Inspection Laboratory in southern California. The following table gives a summary of the results for the year 1919.

TABLE 19.—CUT-OUT TESTS OF PEACHES IN No. 2½ CANS
(Made by the National Canners' Laboratory, 1919, by H. M. Miller and W. D. Bost)

New grade*	Old grade*	Average original syrup	Average cut-out	Average number pieces	Average net weight, fruit, ounces	Average total net contents ounces	Number of samples
Second	Second	11.80	11.50	18.62	20.85	29.50	858
Standard	Standard	20.92	14.76	14.68	20.37	29.75	1,140
	Extra Standard	31.30	17.14	12.70	20.20	29.80	1,101
Choice	Extra	40.30	19.77	10.98	19.54	29.95	633
Fancy	Special Extra	53.00	24.75	9.90	17.95	30.50	21

* "New grade" refers to Canners' League grades, and "Old grade" to grades in use in 1919 and since superseded by the Canners' League grades.

The results indicate that the recent ruling of the Department of Agriculture that No. 2½ cans of peaches contain 20 ounces drained weight of fruit is rather a severe condition to meet in commercial practice. By use of the data given in this table it will be possible to determine rather accurately the grade of any given sample of canned California peaches.

The cut-out test varies considerably with the variety of peaches, their maturity, the ratio of fruit to syrup and with the locality and season.

Yields and Waste.—According to Zavalla, a former graduate student at the University of California, there is obtained from a ton of peaches an average of 40 cases of 24 No. 2½ cans each. According to the Dunkley Canning Machinery Company, the average yield is 44 to 46½ cases of cling peaches and 39.8 to 42.75 cases of freestone peaches per ton with use of the spray lye peeler. Their data cover a number of canneries and several seasons' observations. Commercial canners have reported to the writer average yields of from 40 to 42 cases of cling peaches per ton. The pits represent about 12 to 18 per cent of the weight of the fruit and the loss in peeling 12 to 20 per cent. The total loss in preparation averages about 30 to 35 per cent.

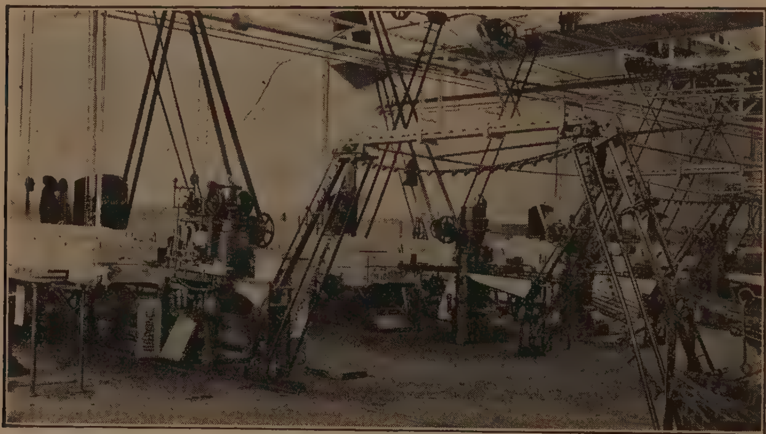

FIG. 30.—Overhead can conveyor from sealers to sterilizers. (*Courtesy, H. G. Prince Cannery, California*).

The pits are spread in the sun to dry and in most canneries are used at the cannery for fuel or sold locally to cannery workers or others for fuel purposes. During the war large quantities of the pits were cracked and the shells were used for the preparation of a carbon of high absorptive power for use in gas masks. The kernels, which comprise about 15 per cent of the weight of the pits, can be recovered and used for the preparation of sweet oil and bitter almond oil, but the cost of recovery is so high that the products cannot economically compete with those from apricot kernels.

The waste lye solution containing the peels and the waste wash water is of no economic value and its disposal in some localities has presented a serious problem because the sodium hydroxide renders the soil alkaline and toxic to plants. Further discussion of the utilization of peach and other fruit and vegetable wastes will be found in Chapter XXVII.

Labeling and Packing.—Canned peaches and other canned fruits and vegetables in cylindrical cans are labeled by portable automatic machines. The cans are placed in a runway above the machine by a workman and pass by gravity through the machine. The cans first pass over small rollers which apply the label paste, which may be glue, a casein preparation, dextrine mucilage or other adhesive. They next roll across a stack of labels, one of which is picked up by the label paste on the can and is smoothed in place automatically by the machine. Adhesive is applied automatically to the end of the label and the label end sealed to the can.

Boxes.—The labeled cans are packed at once into cases, 24 cans of No. 2½ and 48 of small size cans per case, or 6 No. 10 cans per case. Wooden cases are most commonly used, although fiber board (heavy pasteboard) and corrugated fiber board boxes are being rapidly adopted by some canners. (See Chapter XXIX for full discussion of boxes.)

APRICOTS (*Prunus armeniaca*)

The apricot is second in importance to the peach among California canned fruits. The normal pack of canned apricots is 3,000,000 cases, which represent about 60,000 tons of fresh fruit. This quantity is slightly less than the normal tonnage of fresh apricots dried in California. At an average price of 16 cents a pound for the dried fruit, and a yield of 400 pounds of dry fruit per ton of fresh, a ton of fresh apricots will yield a gross revenue of about $64, whereas a ton of the fruit after canning will yield at $2 per dozen No. 2½ cans, approximately $220. Canning is much more costly than drying. In most cases the over-ripe fruit is dried and the prime ripe fruit is sent to the cannery or fresh market.

Varieties.—The Blenheim apricot is the most popular variety for canning purposes. It is of moderate size, deep yellow color, of excellent flavor, reasonably free from scab or blemishes and when properly ripened is of uniform texture from the skin to the pit and retains its shape in the can during processing. It is grown most extensively in the counties bordering the San Francisco Bay region in California.

The Royal apricot is grown in southern California and in the hot interior valleys. It is somewhat smaller in size than the Blenheim and of a more intense orange color. However, it is claimed by many nurserymen that the Royal and the Blenheim are identical and that the differences in appearance noted in commercial culture are due entirely to the effect of locality and to climatic conditions. The Royal apricot grown in hot, dry sections often becomes soft near the pit, a condition which renders it more or less unsuitable for canning purposes.

The Moorpark is a very large variety, which is grown in a limited way in central California. This variety does not bear as heavily nor as uni-

formly as the other two varieties and tends to ripen unevenly. Its large size and excellent quality make it very much in demand for sale in the fresh fruit markets.

Other varieties canned in small quantities are the Tilton and Hemskirk.

Harvesting.—The fruit on the tree is at its optimum degree of maturity for canning purposes for 1 or 2 days only. If it is too green the canned fruit will have a disagreeable astringent flavor, and no amount of sugar will entirely overcome this defect, and if over-ripe it will be too soft and will be unattractive in appearance after sterilization. When gathered at the "canning ripe" stage of maturity the fruit is of full size, of good color, firm and of pleasing flavor. It will not have reached the maximum flavor, however, at this stage of ripeness.

The canner desires that the finished product shall retain its clear-cut appearance and that the syrup shall remain clear and reasonably free from pieces of broken fruit. At the same time it is necessary that the fruit have a reasonable amount of flavor. To obtain these results, the apricots should be transported to the cannery as rapidly as possible after gathering and should, if possible, be canned on the same day they are picked, as they cannot successfully be shipped long distances. The wagons or trucks used in transporting them should be equipped with good springs to prevent bruising of the fruit in transit.

Apricots are subject to brown rot, *Sclerotinia fructigena*, a fungus which attacks the flowers and green shoots during the spring and the ripe fruit in foggy or rainy weather. It sometimes attacks the fruit in the lug boxes.

Receiving.—Most canners examine each delivery of apricots to determine roughly the percentage of the different grades, and payment is made to the grower on the basis of this "door test." For example, in a typical test, in 1921, 25 pounds of a mixed sample were taken for a grading. Three grades were made, and designated as grades A, B and C. There was found to be 17 per cent of A, 72 per cent of B and 11 per cent of C grade respectively for which the grower was paid at the rate of $60, $25 and $12 respectively.

Many canners make only two grades, namely, A and B, often paying half as much or less for the B grade as for the A grade.

Preparation and Canning.—The apricots are halved and pitted but are generally not peeled.

Pitting.—The fruit is cut by hand around the pit suture and the pits removed. A small proportion of the crop, however, is lye peeled in the same manner as described for peaches, although the lye used is weaker than that used for peaches. The grading of the halved and pitted fruit is carried out in the same manner as described for peaches. For size grades, see chapter on grading (VII).

Slicing.—A small amount of the largest fruit is sliced and canned for a special trade. It is an excellent article and deserves greater popularity.

Grading.—Screens of $^{40}/_{32}$, $^{48}/_{32}$, $^{56}/_{32}$, $^{64}/_{32}$ and $^{68}/_{32}$ of an inch are used. The average diameters of the Fancy, Choice and Standard grades are $^{56}/_{32}$, $^{54}/_{32}$ and $^{50}/_{32}$ of an inch respectively.

Canning.—The graded fruit is transported to the canning tables on belts in the manner described for peaches, and at the canning tables the fruit undergoes operations similar to those described for peaches, namely, sorting, washing and filling into the cans by weight.

Syruping.—The filled cans are syruped in the automatic syruping machines with syrups of the concentrations recommended by the California Canners' League of 55, 40, 25, 10° Balling and plain water, according to whether the grade is Fancy, Choice, Standard, Second or Pie. Some canners use syrups 5° Balling richer in sugar than those given above.

Owing to its high acidity the apricot is not pleasing in flavor as a dessert fruit unless it is canned in a heavy syrup, 40 to 55° Balling. There is, however, a good demand for it in lighter syrups and in water for the making of pies.

Exhausting.—Apricots must be very thoroughly exhausted in order to reduce the action of the fruit acid on the tin plate, and in addition the cans should be well filled to reduce the head space. An exhaust of 10 minutes at 180°F. is to be preferred to 4 minutes' exhaust at 205°F., because the longer exhaust removes the air more completely and results in less softening of the fruit.

Sterilizing.—After exhausting and sealing, the cans are immediately sterilized, usually in agitating continuous cookers. The time of sterilization at 212°F. varies from 4 to 15 minutes, depending upon the locality and upon the variety and maturity of the fruit. In southern California, in 1920, Royal apricots were sterilized in agitating cookers for 4 minutes at 212° with good results. At San Jose in the same year, Blenheim apricots were sterilized for 10 to 12 minutes in agitating cookers. Too prolonged sterilization will soften the fruit badly. Very little softening of the apricots by cooking is required, and for this reason the cans should be thoroughly and quickly cooled after sterilization.

Canned Pulp.—Some fruit, particularly that which is over-ripe, is pulped in tomato pulpers, concentrated with sugar and canned for use in making pies, etc. In many canneries the Pie-grade fruit is steamed thoroughly to soften it and is packed as solid pack fruit without the addition of water or syrup. It requires heavy sterilization because of slow heat penetration.

Yields.—The average yield of canned apricots per ton is about 55 cases of 24 No. 2½ cans. The loss in canning of the unpeeled halved

fruit is about 9 to 15 per cent. Where the fruit is peeled the loss will exceed 30 per cent, based on the weight of the fresh fruit.

Apricot pits are in demand for the manufacture of by-products such as "almond oil," sweet and bitter, and macaroon paste. They are usually dried by spreading in the sun, to a depth of about 1 foot, on a cement floor or on rolled ground, stirred daily until dry and then placed in sacks to be shipped to by-products plants. Apricot pit by-products are described in Chapter XXVII.

Cut-out Tests.—The National Canners' Association Inspection Laboratory in southern California has made a careful study of the composition of syrups added to the fruit at the time of canning and the composition of the syrups on the cut-out test after canning. The following table gives a summary of the data of 1919.

TABLE 20.—CUT-OUT TESTS FOR APRICOTS

National Canners' Association, 1919

(*After Miller and Bost*)

New grade	Old grade	Net contents	Net drained weight	Balling degree of syrup	
				Original	Cut-out
Second..........	Second	30.1	18.0	10.9	12.3
	Standard	30.4	17.9	20.5	15.5
Standard........	Extra Standard	30.6	17.8	30.6	18.3
Choice...........	Extra	30.8	17.5	39.7	21.4

The tests were made before the adoption of the California Canners' League standards. It will be noted that the net weight of drained fruit is somewhat lower than for peaches, owing to the greater tendency of apricots to soften and shrink during sterilization.

APPLES (*Pyrus malus*)

The apple is canned extensively in the Pacific Northwest and the eastern United States, particularly in New York and Pennsylvania. It is used principally for the preparation of pies and sauce in restaurants, hotels, cafeterias, etc. Housewives prefer to use the fresh product or the dehydrated article.

The canning of apples is considered a by-product industry in most apple growing districts and as a means of utilizing the best quality of culls. The fruit for canning purposes should be of fair size and reasonably free from blemishes. Apples unfit for canning may often be used for cider or vinegar.

Varieties.—Apples for canning should be firm and hold their shape in the can, and should be of good flavor, color and texture. Acid varieties of white flesh are preferred.

On the Pacific Coast the Yellow Newtown Pippin and the Spitzenberg are popular for canning purposes. Rome Beauty, Winesap or other firm apples of white flesh and of pronounced apple flavor, and which can be obtained in commercial quantity, can be used successfully. Mealy varieties, or those that become "apple sauce" during processing or take on a pink or yellow color when cooked, are not so desirable for canning.

Peeling and Coring.—The fruit should be washed and sorted before it goes to the preparation tables. It is peeled by mechanical peelers, operated either by hand or by power; in either case the apples are placed on the peeling knives of the machine by hand. The peeled and cored fruit is trimmed by women who work at another table, to which the fruit is delivered by belt or truck; those who do the trimming also cut the fruit in quarters. Ordinarily the fruit is put immediately in dilute brine to prevent oxidation and browning. The peels and cores, which normally represent from 30 to 40 per cent of the weight of the fresh fruit, are usually sent to the vinegar factory to be crushed and pressed for vinegar, although some factories have found it profitable to dehydrate the peels and cores for the use of jelly and pectin manufacturers, from whom there is a rapidly growing demand.

Blanching.—Before the apples are canned they are usually blanched in one of several ways. A simple process of blanching consists in passing the quartered apples through a steam box to soften them and destroy the oxidase and to expel the air from the fruit and thereby reduce pinholing of the tin plate.

In some canneries the fruit is immersed in boiling 3 per cent brine for 3 or 4 minutes to accomplish the results mentioned above.

It is possible to remove the air by placing the fruit in dilute brine or water and subjecting it to a high vacuum. The air is effectively removed and water enters the fruit tissues to replace the expelled air, increasing the weight of the fruit considerably. Another method in fairly common use consists in heating the fruit several hours in water at 120°F.

Canning.—Following the blanching operation the hot fruit is packed at once into No. 3 or No. 10 cans as a solid pack, or a small amount of boiling hot water or dilute brine is added. In most cases, however, the can is practically filled in solid-pack style and very little liquid is necessary.

Exhausting.—More trouble has been experienced by the corrosion and pinholing of tin plate by apples than by other canned fruit. It has been proved by Bigelow and other investigators that the corrosion is caused by the malic acid of the apples in the presence of air or oxygen and that corrosion is limited or reduced to a negligible degree if the air is

thoroughly expelled from the fruit by blanching and from the can and contents by thorough exhausting.

Sterilizing.—Apples are easily sterilized on account of their high acidity, but owing to the fact that the fruit is packed tightly in the cans, heat penetration is not very rapid. Nevertheless a sterilization of 8 to 10 minutes at 212°F. in an agitating continuous sterilizer is sufficient.

Pinholing of Tin Plate by Apples.—As noted above a serious problem in the canning of apples is the frequency of corrosion of the tin plate. As proved by Bigelow, Huenick, Wiegand, Todd and others, blanching and thorough exhausting are the most effective means of preventing corrosion. Huenick, chemist of the American Can Company, recommends the use of a heavy tin plate, *viz.*, "Char A-1," and finds that this is more desirable than lacquered tin plate, for the reason that the latter often has small areas that are not perfectly covered with the lacquer.

Corrosion is favored if the cans are allowed to remain hot for several hours after sterilizing. It has been found desirable to invert the cans in the warehouse 3 days after canning and again at 3-week intervals during storage, for the reason that corrosion takes place at the water line in the can and if the can is inverted frequently corrosion is distributed over a greater surface. See Chapter XIV on "Spoilage of Canned Foods" for further discussion of pinholing of tin plate.

BLACKBERRIES (*Rubus villosus*)

Large quantities of blackberries are canned in the Pacific Northwest for use in the preparation of pies.

Varieties.—In Oregon and Washington, the Evergreen variety, which is an improved strain of the wild blackberry, is most popular.

In California the principal variety is the Mammoth blackberry, which is a hybrid similar in composition and flavor to the loganberry. It is very large, of good color and of high acidity.

The Lawton blackberry ripens later than the Mammoth blackberry, and is smaller and sweeter. It is excellent for jams and preserves and is more in demand for this purpose than for canning. The Himalaya blackberry, a small berry of good color and flavor, ripens in August, September and October, and is canned in small quantities, but owing to the fact that it ripens late in the summer it is more in demand for the fresh market than for canning. Any good table variety may be used for canning.

Harvesting.—Blackberries should be harvested in shallow boxes and should be picked frequently, daily if possible, in order that the fruit may be at the optimum stage of maturity. It is desirable that the fruit be canned on the same day that it is picked, otherwise serious

deterioration will take place, even with the greatest care in transportation and storage.

Canning.—At the cannery the fruit is generally merely sorted and very thoroughly washed, very little attempt being made to grade for size. Since most of the fruit is used for pie making rather than for dessert purposes, it is generally packed in water or in light syrups. Fruit for dessert purposes should be packed in syrup of 50 to 55° Balling; lighter syrups do not bring out the rich blackberry flavor, and syrups above 60° Balling cause the fruit to shrivel and become tough.

Because of its very high acidity this fruit must be very thoroughly exhausted, otherwise pinholing and corrosion will be excessive. The length of sterilization required is very short for the reason that the fruit is acid in character and easily sterilized. Eight or ten minutes at 212°F. is sufficient.

In plain tin cans the color of the syrup and of the fruit bleaches rapidly. Therefore it is customary to can the berries in enamel-lined (lacquered) cans.

The fruit may also be canned as a light preserve after boiling 3 to 4 minutes with an equal weight of sugar. In this case no syrup, except that found in cooking, is added.

LOGANBERRIES

Oregon is the largest producer of loganberries and more loganberries are canned in that state than in all other states combined. The berries are very large in size and deep red in color.

The fruit is most in demand for pie making purposes and therefore is canned in No. 10 enamel-lined cans. The processes of harvesting, canning and sterilizing are practically the same as for blackberries. Lacquered cans must be used to insure the retention of color.

RASPBERRIES (*Rubus strigosus*)

Raspberries are grown throughout the United States and canned in commercial quantity in the northern and middle Western States, in New York and on the Pacific Coast. The red raspberry is preferred to the black variety for canning purposes but is more in demand for the preparation of preserves and jams than for canning. The berries are canned in lacquered cans in heavy syrup for dessert purposes and in water for use in pies. The length of sterilization is usually about 12 minutes at 212°F. They may also be canned after cooking a short time with half their weight of sugar.

STRAWBERRIES (*Fragaria virginiana*)

Strawberries for canning purposes should be firm in texture, of good color, flavor and of large size. The most important requirement is firm texture. The principal difficulty in the canning of strawberries is the softening of the fruit during sterilization, which results in the can containing only from one-third to one-half its volume of berries. Strawberries are used for preserves and for packing in dry sugar in cold storage in very much larger quantities than for canning.

Strawberries shrivel if canned in too heavy a syrup, although a fairly heavy syrup is necessary to develop and retain the berry flavor. A syrup of 50° Balling is satisfactory. Strawberries are much more satisfactory for preserving than for canning.

OTHER VARIETIES OF BERRIES

Currants and gooseberries are canned only in very small quantities, and may be used to better advantage in the preparation of preserves, jams and jellies.

Blueberries grow wild in abundance in the North Atlantic States, Alaska and in Scandinavia, where they are gathered and canned for use in pies. According to Bitting, leaves and stems are separated from the berries by a blast of air and the berries are carefully hand stemmed and sorted. They are usually canned in water, although they are of better flavor if canned in a syrup of 30° Balling.

CHERRIES (*Prunus cerasus*)

The principal districts in which cherries are grown for canning purposes are New York, Michigan, Oregon and California. In the Eastern States the sour varieties are most commonly used, whereas on the Pacific Coast a sweet cherry, the Royal Anne, is the principal variety used for canning. This is a large, sweet variety of white or light pink color.

Preparation.—After its arrival at the cannery in most plants, the fruit is first stemmed by hand, although an efficient mechanical machine is now in use in a few canneries. This machine consists of a slightly inclined cylinder about 4 feet long and about 2 feet in diameter, which rotates at about 20 to 30 revolutions per minute. The cylinder is made up of a series of short rubber rollers about 3 feet long and about 1 inch in diameter. As the cylinder rotates, the rollers are enmeshed at one end by a cog wheel when the rollers are at the lower position during rotation. As the rollers turn they catch and pull through stems and leaves, leaving the cherries uninjured on the inside of the cylinder. The cherries are fed in at the upper end of the cylinder and emerge at

the lower end with 95 per cent or more of stems removed. Following the stemming the fruit is thoroughly washed.

It then goes to the same machine used for the grading of peaches and apricots, except that screens with holes of smaller diameter are used. The usual sizes of screen used in the grading of cherries are $^{20}/_{32}$, $^{22}/_{32}$, $^{23}/_{32}$, $^{26}/_{32}$, $^{28}/_{32}$, $^{30}/_{32}$ and $^{32}/_{32}$ of an inch.

TABLE 21.—GRADING SCREENS FOR CHERRIES

(*After A. W. Christie*)

Variety	Size of screen, inches	Number of cherries per No. 2½ can
Soft Small White	$^{26}/_{32}$	115
	$^{25}/_{32}$	120
	$^{24}/_{32}$	134
	$^{23}/_{32}$	145
	$^{22}/_{32}$	158
	$^{20}/_{32}$	206
	over end	261
Black Tartarian	$^{26}/_{32}$	105
	$^{25}/_{32}$	125
	$^{24}/_{32}$	142
	$^{23}/_{32}$	156
	$^{22}/_{32}$	175
	$^{21}/_{32}$	210
	over end	220
Royal Anne	$^{30}/_{32}$	70
	$^{29}/_{32}$	83
	$^{28}/_{32}$	87
	$^{27}/_{32}$	94
	$^{26}/_{32}$	110
	$^{25}/_{32}$	115
	$^{24}/_{32}$	135

These screens yield the grades established by the Canners' League of California.

Pitting.—Most of the sweet cherries are canned without pitting although a large proportion of sour cherries are pitted. The pitting is accomplished by an automatic machine in which cherries fall into small cups and in which the seeds are removed by cross-shaped plungers. The loss in pitting is about 15 per cent of the weight of the stemmed cherry.

Syrups.—The highest grade of cherries receives a syrup of 40° Balling. Syrups of greater density than this cause the fruit to shrivel. The other grades receive in California 30, 20 and 10° syrups and water respectively.

Exhausting.—Cherries should receive a long exhaust, at least 10 minutes at a moderate temperature, at 165 to 185°F., in order to eliminate air and to prevent pinholing. This is particularly desirable for sour cherries, which corrode tin plate rapidly.

Sterilizing.—The length of sterilization is from 12 to 25 minutes at 212°F., depending upon the variety and maturity of the cherries.

GRAPES (*Vitis vinifera*)

The only grape canned in commercial quantities is the Muscat of Alexandria, the highly flavored, sweet European variety of raisin grape grown in California.

The bunches possessing the largest berries are selected for canning purposes. At the cannery the fruit is removed from the stems by hand and defective berries removed and discarded. It is then taken immediately to the graders fitted with $^{20}/_{32}$, $^{21}/_{32}$, $^{24}/_{32}$ and $^{26}/_{32}$ of an inch openings. The graded fruit is washed, packed into No. 2½ or No. 10 cans and the cans are filled with syrups of 40, 30, 20 and 10° Balling, and water respectively for the five grades. After exhausting and sealing, the fruit is sterilized for 12 minutes at 212°F.

Red grapes are sometimes canned in lacquered cans in their own juice, without the addition of sugar, and given a short sterilization, either at 185 or at 212°F.

PEARS (*Pyrus communis*)

On the Pacific Coast the Bartlett pear is the variety almost exclusively used for canning, and in the eastern United States the Kieffer is used, because the Bartlett cannot be grown successfully on account of its susceptibility to blight. The Bartlett pear is desirable because of its uniform shape, white color and its relatively small number of grit cells. The Kieffer pear is smaller than the Bartlett and of less desirable color and texture.

Harvesting and Ripening.—Pears develop a better flavor and are of finer grained texture if ripened in boxes after picking. Fruit ripened on the tree is apt to be coarse in texture. The pears are gathered at full size, but while they are still hard and green, and are shipped in this condition direct to the cannery where they are held for from 5 to 10 days to ripen.

The fruit does not ripen evenly in the boxes and it is therefore necessary to sort it daily during the ripening period in order that fruit of the optimum degree of maturity for canning may be obtained. The fruit

ripens best at a temperature of about 70°F., preferably in a well-ventilated room. If the pears must be held 10 days or more they are placed in cold storage at 32 to 36°F.

Preparation.—The fruit is peeled, halved and cored by hand, a special guarded knife being used for peeling, the direction of peeling being from the stem toward the calyx, and not around the pear. The core, stem and calyx are removed by a loop-shaped knife. (See Cruess and Christie's "Laboratory Manual" for appearance of pear peeling and coring knives.) At the same time the fruit is graded by hand according to size, usually five grades being made in accordance with the standards of the Canners' League of California, as given in Chapter VII. The Fancy grade represents 8 to 10 pieces, the Choice 10 to 12 and the Standard 12 to 17 pieces per No. 2½ can.

Pears oxidize and turn brown very rapidly after peeling and if they are to be held for more than a few minutes they should be placed in dilute brine, 1 to 2 per cent salt, or in water. Brine checks the action of oxidase, the enzyme responsible for browning.

In some canneries pears are now peeled by treatment of the whole fruit in superheated steam.

The waste during peeling, coring and stemming is usually 30 to 35 per cent. The cores and peels can be used in the preparation of vinegar or denatured alcohol, although in most factories the waste material is discarded.

Canning and Sorting.—At the canning tables the fruit is again sorted for quality and size. If the surface of the fruit has become browned the women at the canning tables remove the brown surface by vigorous rubbing of the pears with the palm of the hand.

Syruping.—The syrups used for the different grades are 40, 30, 20 and 10° Balling and water respectively. Owing to the pear's low acidity the 40° syrup is sufficient for the best grade and syrups higher in sugar than 40° Balling impart too sweet a taste.

Sterilizing.—In an agitating cooker, pears require a sterilizing time of approximately 17 minutes at 212°F. In non-agitating cookers at 212°F. the processing time is about 25 minutes.

Thorough cooling after sterilizing is necessary, otherwise some of the fruit is liable to turn pink in color, as is the case with peaches.

PLUMS (*Prunus domestica*)

The large, sweet varieties of white plums, such as the Green Gage and Yellow Egg, are in greatest demand for canning purposes; the red and black varieties are seldom used.

The plums are sorted and the stems and leaves removed, after which they are graded on vibrating screens containing circular openings of

$^{32}\!/_{32}$, $^{40}\!/_{32}$, $^{48}\!/_{32}$ and $^{56}\!/_{32}$ of an inch in diameter. Fancy-grade plums are $^{56}\!/_{32}$ of an inch, Choice $^{50}\!/_{32}$ and Standard-grade plums $^{42}\!/_{32}$ of an inch in diameter.

Plums soften badly in the sterilizing process so that it is difficult to obtain well-filled cans and on account of their very high acidity there is serious danger of pinholing and corrosion of the tin plate unless the fruit is very thoroughly exhausted. The use of heavily coated tin plate and the application of a thorough exhaust will greatly reduce loss by this type of spoilage. Plums are sterilized from 8 to 14 minutes at 212°F.

FIGS (*Ficus carica*)

Figs are canned extensively in Texas and California and small quantities are canned in some of the other Southern States, particularly Louisiana. In California two varieties are used for canning purposes, *viz.*, the Smyrna or Calimyrna, and the Kadota. The Kadota, a white fig of moderate size, of thin skin, firm flesh and small seed cavity, is an important canning variety. The Calimyrna is a very large variety which during its growth on the tree, requires artificial pollination or caprification, through the agency of the fig wasp, *Blastophagus*. The Smyrna is not as desirable for preserving purposes as the Kadota for the reason that its seeds are large, the flesh thin and soft and the skin inclined to be tough. It is, however, very rich in flavor, high in sugar and excellent for canning.

In Texas the Magnolia fig is most commonly used, and in Louisiana the Celeste. The Magnolia fig is light brown in color, of moderate size and of excellent canning and preserving quality. The Celeste fig is very small and much elongated but in addition to possessing a very rich flavor is very firm and retains its form and texture remarkably well in preserving or canning.

Usual California Process.—The figs are graded for size by a roller grader into four grades. They are then blanched in water at about 150°F. for about 5 to 10 minutes, the time depending on the size and maturity. They are then sorted into two quality grades, broken and sound, and are canned in No. 1 tall, No. 2½, No. 10 and Eastern Oyster sizes of cans. A syrup testing 65° Balling hot (about 72° Balling at 60°F.) is added boiling hot. The cans are usually exhausted 8 minutes at 190°F. and sealed at once. They are sterilized in boiling water without agitation as follows: No. 10 syrup pack, 2 hours; No. 10 water pack, 1 hour; No. 2½ syrup pack, 1 hour and 50 minutes; No. 1 tall, 1 hour and 40 minutes; and Eastern Oyster, 1 hour and 35 minutes.

Texas Process.—In Texas the figs are peeled in a dilute boiling lye solution and the peels are removed in running water or under streams of water. The fruit is cooked in a heavy syrup to a preserve before can-

ning. Further details of this process will be given under the "Preparation of Fig Preserves," Chapter XVIII.

ORANGES (*Citrus sinensis*)

Sliced peeled oranges have been canned in California for the use of seagoing vessels and for sale in England, but the demand has been limited. The process used was to heat the sliced peeled oranges in a heavy syrup, approximately 50° Balling, for several minutes at 175 to 185°F. The thoroughly heated fruit and syrup were then placed in cans and pasteurized at not above 185°F. The flavor of the oranges deteriorates after canning and the product is not very palatable after several months' storage.

POMELO, GRAPEFRUIT (*Citrus grandis*)

Grapefruit is now canned commercially in Florida, Porto Rico and California for use as a breakfast dish. The fruit is soaked in cold water a few hours to soften the peel and is then peeled and cored by hand. The segments are then separated and peeled by hand, a very laborious and expensive proceeding. Recent experiments prove that the segments may be peeled readily by a boiling, 1 per cent lye solution.

The peeled segments are canned in a dilute syrup or sweetened juice, the cans thoroughly exhausted, sealed and sterilized at about 180°F. Higher temperatures injure the flavor.

Canned grapefruit has proved very popular.

RIPE OLIVES (*Olea europea*)

Owing to the fact that the canning operation represents an incidental step in the preparation of ripe olives, a separate chapter will be devoted to the pickling and canning of this fruit (see Chapter XII).

PINEAPPLES (*Ananas sativa*)

Pineapples were canned in Maryland in a small way early in the history of the canning industry, the fruit being shipped to the canneries from Florida, but the Hawaiian Islands now produce most of the canned pineapple of the world.

Pineapples were first grown in the Islands for export in the fresh condition to the mainland, but it was soon found that the market for the fresh fruit was limited and that in order to insure arrival of the fruit in sound condition it was necessary to pick it before it had reached maturity. The canning of the field-ripened fruit then followed as a natural sequence.

Growth of the Pineapple Canning Industry.—The increase in the production of canned pineapple during the past 20 years is shown in the following table:

TABLE 22.—PRODUCTION OF CANNED PINEAPPLE IN THE HAWAIIAN ISLANDS COMPARED WITH CANNED PEACHES IN CALIFORNIA

Year	Pineapple, cases (1 case equivalent to 24 No. 2½ cans)	Peaches, cases
1900	9,800	907,000
1910	625,000	2,145,000
1915	2,700,000	3,239,600
1920	6,752,000	5,731,000

Harvesting.—The fruit is allowed to reach full maturity before it is picked, because if harvested too green and allowed to ripen in boxes it will be lacking in flavor; if allowed to become over-ripe, fermentation will set in and the fruit will be worthless for canning purposes.

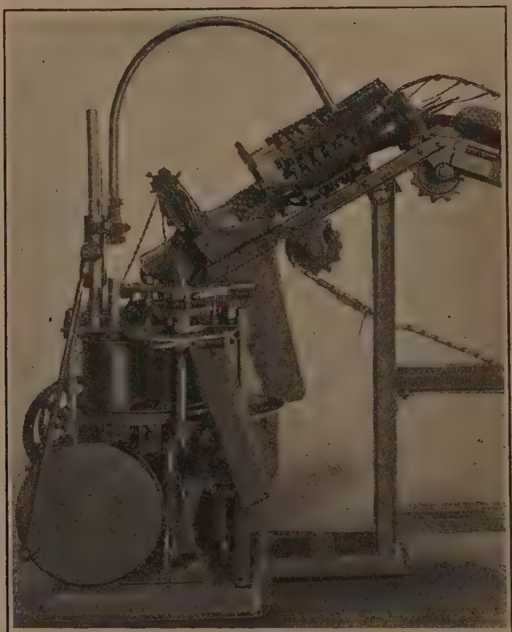

FIG. 31.—A Ginaca machine for peeling and coring pineapples for canning. (*Courtesy, Anderson-Barngrover Mfg. Company*).

In picking the fruit, laborers pass between the rows and break the ripe "pines" from the plants by bending them sharply. The fruit is then carried to the nearest roadway where the crowns are cut off and the fruit placed in lug boxes, in which it is taken at once by rail to the canneries.

Most of the fruit is harvested during the months of July and August, although a second crop is gathered in December and January.

Peeling and Coring.—Upon arrival at the plant the fruit is stored out of doors on a large receiving platform, and is trucked by hand from the platform to the peeling and coring machines, known as "Ginaca machines." This machine is entirely automatic in operation and performs the operations of cutting off both ends of the fruit, sizing, coring and removing the outer shell (see Fig. 31).

Trimming.—A considerable proportion of the fruit contains adhering pieces of shell which must be trimmed before slicing and the cored cylinders of pineapple drop from the Ginaca machine on to a broad rubber belt which carries them before women, who carefully inspect each fruit and trim off pieces of shell or blemishes. The pineapple contains an active proteolytic enzyme, making it necessary for the women to wear rubber gloves to protect their hands.

Slicing.—The trimmed fruit is carried by means of a second belt to the slicing machine, but is thoroughly washed enroute. The usual thickness is such that eight pieces will fill a No. 2½ or No. 2 can. Each cylinder is cut into circular pieces automatically by the knives of the slicing machine.

Sorting.—The sliced fruit is carefully inspected and sorted by women as it is carried from the slicing machine on rubber belts. The most perfect pieces are removed first and constitute the highest grade; the second and lower grades are removed as the fruit progresses and the broken slices and ends are allowed to pass over the end of the belt to be canned as broken slices.

Syruping.—The filled cans are syruped automatically in much the same manner as described elsewhere for peaches and other fruits. In several of the larger canneries the waste from the Ginaca machines and trimming belts is crushed and pressed. The resulting juice is filtered and neutralized with calcium carbonate at the boiling point, filtered a second time to recover calcium citrate, then decolorized with decolorizing carbon and concentrated in vacuo. It can then be mixed with cane sugar syrup and used in canning. The pomace is returned to the fields to furnish humus.

This process was developed by Charles Ash and Ralph Gould, chemical engineers of San Francisco, Cal.

In some of the plants attempts are being made to market some of the surplus juice and syrup in bottles or cans for soda fountain and household use. In one factory, the juice has been concentrated by freezing and separation of the resulting ice and syrup.

Exhausting and Sterilizing.—The filled cans of pineapple are exhausted in steam exhaust boxes at 185 to 204°F. for 4 to 6 minutes, as described for other fruits.

The cans are then sealed in automatic double-seamers and sterilized in agitating continuous cookers at 212°F. for about 10 minutes.

Grated Pineapple.—Recently there has been developed a machine known as an "eradicator," which is equipped with an adjustable knife set at an angle and with rollers which carry the shells from the Ginaca machine beneath and against the knife. Most of the pulp is cut or scraped from the shells and drops to a broad sorting belt, beside which stand women who remove "eyes" and pieces of shell.

The pulp is then grated or crushed, packed into cans, syruped, exhausted and sterilized. It is used extensively for pies, cakes, confections and salads but is less popular than the sliced fruit for dessert purposes. The product, in spite of the fact that it is in the nature of a by-product, has real merit and its use should increase.

Disposal of Cores.—Most of the cores are crushed and pressed for juice, although a limited amount is canned for confectioners' use or is candied.

Grades.—According to Bitting the following grades are recognized:

Extra.—Perfect pieces, free from eyes or portions of eyes, free from peel, fruit of perfect color (light yellow), of tender texture, but firm enough to hold up in processing.

Extra Standard.—Perfect slices with all characteristics of extra grade, but may be lighter in color, or a little greener.

First Standard.—Sound fruit with some imperfections in color, or in cutting and may exhibit some variation in ripeness or color.

Second Standard.—Contains more light fruit and imperfect pieces than the First Standard grade.

Fifth Grade.—Broken pieces and irregular or spotted slices.

The fourth and fifth grades are usually shredded or crushed. According to Bitting, the syrups used for the three highest grades are 55, 50 and 40° Balling respectively. The cut-out tests should be above 25, 23 and 20° Balling respectively.

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CHAPTER XII

PICKLING AND CANNING OF OLIVES

According to certain ancient writers olives were pickled in a crude way in salt or were treated with wood ashes to remove the bitterness, and to preserve them. Methods of pickling now in use are of comparatively recent development.

Extent of Industry.—The California ripe olive has appeared on the market only during the past 20 years, but in that relatively short period ripe olive canning has become an important industry. The usual annual production in California is about 275,000 cases, or approximately 1,500,000 gallons of canned, ripe, pickled olives. The United States imported in the year 1920 more than 5,000,000 gallons of green olives. The consumption of ripe olives in the United States, therefore, is approximately only one-fourth that of imported green olives.

About 1900, F. T. Bioletti of the University of California, discovered that ripe olives, after a preliminary pickling process to remove the bitterness, could be canned and sterilized in the same manner as other food products. The olive pickling factories of the state were quick to realize the advantage of this method of preservation and to adopt it.

Varieties.—The most important variety is the Mission, and over 90 per cent of the acreage is of this variety. The fruit is of medium size and oblong in shape with a pronounced point at the blossom end. It is rich in oil, of firm flesh and of excellent pickling quality. It is not as large as the other varieties, but is superior to them in flavor, texture and oil content.

The Manzanillo olive is the second in importance. It is cherry-shaped, slightly larger and ripens about 2 weeks earlier than the Mission and for this reason is preferred to the latter in districts subject to early frosts.

The Sevillano or "Queen olive" is third in importance and is the variety grown in Spain for the preparation of the large Queen green olive. Most of the fruit is an inch or more in diameter, as compared to ¾ inches or less for the Mission. The Sevillano is more tender in texture and very much more difficult to pickle than either the Mission or the Manzanillo. On account of its very large size, however, it is in demand and in certain districts of California the orchardists are grafting the Mission and Manzanillo trees with Sevillano scions.

The Ascalano variety is nearly as large as the Sevillano but its flavor is not as pleasing and the color is generally less intense.

Chemical Composition of Olives.—Unpickled olives are intensely bitter. A number of European chemists, principally Bourquelot, Vintellesco, Power and Tutin, have investigated the chemical nature of the bitter principle. Power and Tutin believe that the bitterness is due to gums or tannin, while Bourquelot and Vintellesco contend that the bitter principle is a glucoside, to which they have given the name "oleuropein."

The bitterness is destroyed by dilute alkali at room temperature and neutralization of the excess alkali does not cause a return of the bitterness after it has been destroyed by the alkali. The bitterness can also be destroyed by treatment with dilute acid in an autoclave under pressure. This would indicate that the bitter compound is hydrolizable. The principal step in the pickling process consists in the destruction of the bitter principle with sodium hydroxide.

The flesh of ripe olives of the Mission variety contains from 20 to 25 per cent oil; that of Manzanillo olives about 16 to 18 per cent and that of the Sevillano and Ascalano varieties less then 15 per cent.

In addition to oil, the fruit contains normally from 6 to 10 per cent of soluble solids, of which mannite is one of the most important constituents. The juice of the Mission olive is acid in reaction and when titrated with one-tenth normal alkali is equal in acidity to a 0.4 to 0.5 per cent citric acid solution. It is probable, however, that the acids in the olive are complex in nature and are not as simple as citric, malic or tartaric acids.

In the pickling process probably most of the soluble compounds are removed by leaching. Olive oil remains in the pickled product as the principal constituent of the flesh, the remainder being principally crude fiber. The following table published by Prof. M. E. Jaffa of the Nutrition Division of the University of California will indicate the comparative fat content of the olive and of several staple food products.

Table 23.—Composition of Ripe Pickled Olives
(*After M. E. Jaffa*)

Food	Water, per cent	Protein, per cent	Fat, per cent	Carbohydrates, per cent	Ash, per cent	Fuel per pound, calories
Olive, ripe	69.60	2.00	21.00	4.00	3.40	958
Olive, green	78.41	2.43	12.90	1.78	4.48	598
Cucumbers, pickles	93.80	1.10	0.40	4.00	0.70	110
Bread	35.30	9.20	1.30	53.10	1.10	1,215
Rice, boiled	72.50	2.80	0.10	24.40	0.20	525
Potato, boiled	75.50	2.50	0.10	20.90	1.00	440

Picking.—For ripe pickling, olives are at the optimum stage of maturity when the color of the fruit has become cherry-red. Fruit that has arrived at the jet-black stage is apt to soften in the pickling process and that which is green in color yields a tough pickled product of poor flavor.

R. W. Hilts,[1] Director of the Pure Food and Drug Laboratory of the U. S. Department of Agriculture in San Francisco, has made a tentative recommendation that the flesh of the Mission olive shall contain at least 17 per cent oil and of the Manzanillo at least 15 per cent oil if the pickled product is labeled "ripe." He has made no recommendation for the Sevillano and Ascalano varieties. If the fruit has reached the cherry-red stage of maturity it will, in most cases, conform to the minimum standards suggested by Hilts.

The unpickled olives are extremely sensitive to bruising and great care, therefore, must be exercised in picking the fruit and transporting it to the factory. Canvas buckets are commonly used in picking and the buckets of fruit are emptied into shallow lug boxes fitted with cleats to protect the olives against bruising, when the boxes are stacked.

In the early districts in California the picking season begins about Oct. 20 and in favorable seasons may last until the first of December.

Holding Solutions.—Most factories do not possess a sufficient number of vats to care for all the fruit as rapidly as it arrives. It is therefore necessary to store a considerable proportion of the crop in dilute brine until the pickling vats become available. It is customary also to ship olives in dilute brine, when they are in transit more than one day. The concentration of the brine ordinarily used for shipping purposes is from 3 to 5 per cent salt, and of that used in the factories for storage purposes from 3 to 10 per cent salt. A 10 per cent solution should be used for storage of more than 2 weeks. A hydrometer known as a "salometer" is employed in testing the strength of the brine. A 3 per cent solution is equal to about 12° salometer and 10 per cent equal to about 40° salometer (see Table 76).

Effects Produced.—The holding solution improves the texture of the fruit and makes it possible to pickle it in a shorter length of time than when pickled directly after arrival at the plant.

Fermentation.—The writer has investigated the changes that take place during the storage of olives in dilute brine and has found that in solutions containing less than 6 per cent salt there is rapid formation of lactic acid, the concentration of the lactic acid normally increasing to about $\frac{4}{10}$ of 1 per cent. It is probable that the lactic acid acts as an antiseptic and checks the growth of putrefactive organisms. It was found that olives stored in water or $1\frac{1}{2}$ per cent brine often become slimy and soft through the growth of mold and putrefactive bacteria. When stored in a brine of 10° salt (40° salometer) the olives did not

develop appreciable numbers of organisms and remained firm. This concentration is recommended after the first 10 to 15 days' storage in order to check growth of gas and slime-forming organisms.

Shriveling.—If the olives are placed directly in a 10 per cent salt solution they are apt to shrivel badly. It is therefore necessary to increase the concentration of the brine progressively by small additions of salt from day to day.

Bleaching.—If bacterial growth is very pronounced the olives become bleached in color. This apparently is caused by a reducing action because the color can be returned to the fruit by oxidation.

Length of Storage.—Storage for 3 weeks or longer in holding solution appears to be desirable if its maximum effect is to be obtained. The length of time that olives may be held in satisfactory condition in a holding solution varies according to the variety of the fruit and the concentration of the brine. Olives have been held for 10 months in a strong brine solution without appreciable deterioration in quality.

Grading before Pickling.—In most factories the olives are graded for size before they are placed in the pickling vats, usually with a grader that consists of several screens made of parallel strips over which the olives are carried by rubber fingers. The fingers prevent lodging of the olives between the wooden strips of the screens. Cherry graders have been employed, but because of the oblong shape of most olives the screens with circular openings do not give satisfactory separation of the olives. The roller grader used for oranges has been successfully modified in size and design to make it suitable for the grading of olives.

The unit for designation of the different size grades is $\frac{1}{16}$ of an inch, the largest being $1\frac{7}{16}$ inch in diameter and the smallest size normally used for pickling $\frac{9}{16}$ inch in diameter. Olives smaller than this are used for oil, olive mince, etc.

It is desirable to grade the olives for size before pickling in order that the action of the lye may be uniform. It requires a much shorter time for the lye to penetrate the flesh of small than of large olives and for this reason if the small and large fruit are pickled in the same vat, the small fruit will be softened and bleached by excessive lye action, or the large fruit will remain bitter. In addition to grading the fruit for size, it is customary in some factories to sort it carefully for color into three grades, respectively, black, cherry-red and green fruit. Over-ripe fruit is more subject to injury by lye action than the green fruit. On this account the sorting of the fruit into grades representing the three degrees of maturity is desirable. (See Chapter VII for size grades for ripe olives.)

Pickling Vats.—Olives are pickled in shallow vats, usually constructed of concrete. These are usually about 8 by 2½ feet and about 2 feet in depth. Circular redwood tanks are also used but concrete vats are less liable to become moldy or infected with bacteria and are more easily

cleaned. The wooden tanks, however, are portable and their use makes it possible to utilize the floor space in the pickling room for other purposes after the pickling season is completed. In most factories the vats are supplied with three overhead pipe lines, one containing water, one dilute lye solution and one dilute brine. In some factories a fourth pipe line conveys compressed air to the vats. The vats are equipped with outlets for discharge of spent lye, brine or wash water into open floor drains (see Fig. 32).

Fig. 32.—Pickling room showing concrete vats and method of stirring olives with compressed air.

First Lye Treatment.—During the pickling process the olives are subjected to several applications of dilute lye. The first application is for the purpose of intensifying the color and not for the purpose of removing the bitterness. The concentration of the first lye solution varies from ¼ of 1 per cent to 2 per cent, depending upon the variety and maturity of the fruit and the pickling process. The usual concentration for the Mission and Manzanillo varieties is from 1 to 1½ per cent, which corresponds approximately to 1¼ to 1¾ ounces of granular 95 per cent sodium hydroxide per gallon of water.

Duration.—In most factories the lye is allowed to remain on the olives until it has penetrated the entire skin of the fruit, but not long enough to penetrate more than 1⁄16 of an inch into the flesh. The flesh of the Sevillano, Ascalano and Manzanillo varieties is very much more sensitive to the action of the lye than that of the Mission. For this reason more dilute solutions are used for these varieties.

Temperature.—The rate of penetration is affected by the lye concentration and by the temperature, increase of either causing increase in the rate of lye penetration. The temperature of the water in most plants is from 45 to 65°F. At this temperature range and with the use of a 1½ per cent lye solution the lye will usually penetrate the olives to the desired depth in less than 8 hours. Where the temperature is less than 60°F. the lye solution should be heated to 60 to 65°F. before application. Some of the olive picklers prefer to use a more dilute lye solution, *e.g.*, of from ½ to ¾ per cent sodium hydroxide, and to allow this to remain on the olives for 24 hours. Experience demonstrates, however, that the stronger lye penetrates the olives more uniformly than do the more dilute solutions. The principal objection to the use of strong lye solutions is that they may cause bleaching of the color of the olives if allowed to remain on the fruit for too great a length of time.

Exposure to Air.—The progress of the lye penetration can be followed by placing a drop of dilute phenolphthalein solution on the cut surfaces of the olives or by noting the discoloration of the flesh caused by the lye. When the skin of the entire fruit has been well penetrated, the lye is removed and the fruit exposed in the vats until black or dark brown in color. Preliminary investigations indicate that the olive contains tannins of the pyrogallol group and that the darkening process is probably very similar to the darkening of pyrogallol in dilute alkalies.

The usual length of exposure is 3 to 5 days. During this exposure to the air the olives must be stirred three or four times daily in order that the darkening may be uniform. If this is not done air is excluded from the surface of the olives at points of contact between the individual fruits and this area remains lighter in color than the fully exposed surface, resulting in a spotted or mottled appearance. The usual method of stirring the olives is to cover them with water and to agitate the liquid with compressed air for 2 or 3 minutes. Or the olives may be covered with water and stirred by means of a wooden paddle. The compressed air is less liable to cause bruising (see Fig. 32).

Other Methods of Darkening the Color.—In several large factories the olives are not exposed to the air following the first lye process, but are covered with water and the water is thoroughly aerated by means of compressed air, delivered to the vats through perforated pipes placed in the bottoms of the vats. The oxygen of the air dissolves in the water to a sufficient concentration to cause darkening of the fruit.

The flesh of the olives darkened by the aerated water process is generally lighter in color than that of olives darkened by exposure to the air. A pickled olive of light colored flesh and dark skin is considered superior to one of dark skin and dark flesh.

Subsequent Lye Treatment.—In most commercial olive pickling plants the olives receive three or four treatments in dilute lye after the first lye treatment and exposure. These subsequent lye solutions usually contain about ½ per cent sodium hydroxide and are usually prepared in progressively decreased concentrations. After each addition of lye the olives are exposed to the air or treated with aerated water to further intensify the color. In a few factories two lye solutions only are used, the first solution to permit oxidation and the second to remove bitterness.

Regardless of the number of lye solutions employed, the last lye solution is used for the purpose of destroying the bitter principle. Therefore it is customary to allow this last lye solution to penetrate to the pit of the fruit.

In most commercial plants the strength of this last lye solution is not sufficient to destroy all the bitterness and the pickler often relies upon leaching out the bitterness with water, following the last lye treatment. However, a better flavor is obtained if the last lye solution is of sufficient strength to destroy the bitterness. If it consists of ½ per cent sodium hydroxide it will, in most cases, remove all trace of bitterness if allowed to penetrate completely to the pit.

The lye penetrates most rapidly at the stem end of the fruit and it frequently happens that the blossom end of the fruit will remain bitter, while the stem end will be free from bitterness. If the lye action is too prolonged, the stem end of the fruit may become bleached in color. It is therefore necessary to note carefully the depth and rate of lye penetration in order that the quality of the fruit may not be injured and also in order that all the bitterness may be removed.

It is not possible to give the length of time of application of these various lye solutions. In most cases a very dilute lye solution, for example, ¼ of 1 per cent, is allowed to remain on the fruit for 24 hours; a more concentrated solution, for example, ½ of 1 per cent, is allowed to remain on the fruit for 3 or 4 hours only during each application. Also the length of exposure between these subsequent lye treatments cannot be given definitely. The usual time between treatments is, however, 24 hours, except between the first and second solutions, the olives being aerated between each lye treatment.

Removal of Lye.—Following the last lye treatment the olives are leached with water until they no longer contain either sodium hydroxide or bitterness. The water is changed frequently, at least twice daily, and is stirred frequently by means of paddles or compressed air. It

usually requires from 5 to 7 days' treatment to remove all of the lye from the fruit. If, however, the olives are stirred continuously with compressed air it is possible to leach the lye from the fruit in much less time.

Effect of Temperature.—Water at 75°F. will remove the lye approximately twice as rapidly as water at 60°F. Although the higher temperatures cause more rapid solution of the lye from the fruit, their use is not advisable for the reason that the growth of bacteria is favored; very frequently fermentation and softening of the fruit occur in factories in which the temperature of the wash water is above 70°F. However, a temperature of 120 to 140°F. prevents fermentation and greatly hastens extraction of the lye.

Fermentation.—At 70 to 75°F. floating and fermentation may be very rapid and cause severe losses. Experiments made in 1921 and 1922 have demonstrated that fermentation of the olives can be checked by heating to 175°F. for 30 minutes, should any evidence of fermentation occur. The heating must be done very carefully in order that the flesh of the olives shall not be broken by contact with jets of steam or by too violent agitation. The most convenient means of heating the olives in the factory consists in drawing off the water from the vat, heating it to the boiling point and returning it to the olives until the desired temperature is obtained. One heating of this sort is usually sufficient to check fermentation and softening.

In addition to the fermentation and softening effects, the bacteria exert a reducing action, because the color of the olives becomes bleached, but will reappear if the olives are given a light lye treatment and are exposed or aerated.

The progress of the washing process can be determined by applying a dilute solution of phenolphthalein to the cut surface of the olives, a 1 per cent solution of this indicator in 95 per cent alcohol being satisfactory for the purpose. The taste of the operator is, however, a more delicate indicator of the presence of lye than is the phenolphthalein.

Curing in Dilute Brine.—After all of the lye has been removed from the fruit it is stored in a brine of about 2 per cent salt (8° salometer) for about 2 days. The concentration is then increased daily until the brine reaches a concentration of 3 per cent (12° salometer). The time usually employed in this treatment is less than a week. Two days' time should be sufficient and storage of the fruit for a longer period is dangerous, because fermentation and other bacterial troubles may arise. In some factories the brine is increased to 5 per cent (20° salometer) and the olives are canned in a more dilute solution. This procedure tends to yield a firmer olive and to obviate salt shriveling in the can.

Sorting and Grading.—The pickled fruit is passed over broad, flat belts and is carefully sorted and graded for color and quality. The bitter fruit, which can be recognized by its mottled color at the blossom

end, is removed and returned to the pickling vats. The well-pickled fruit is usually graded to two or three degrees of color, that is, light brown, dark brown and black. It is also graded again for size, because during the pickling process shriveled fruit becomes plump and increases in size and other changes in size take place. Some factories, however, do not make this second grading.

FIG. 33.—Size grades for California ripe olives. Established by the California Olive Association, 1922.

Canning.—On Apr. 17, 1922, The California Ripe Olive Association adopted the following sizes of cans as standard and it has been agreed that cans packed by the members of the Association shall contain at least the net contents of drained olives noted below.

No. 10 packers' can	68 (later reduced to 66 oz)
Tall quart olive cans	19
Tall pint olive cans	9
Buffet can	5

The broken and soft fruit is sorted out and sent to the oil room. (See Chapter VII for size grades of olives.)

The fruit is packed into tall cans which are considerably different in appearance from the ordinary fruit can. The sizes used most commonly are known as tall pints, tall quarts and ordinary No. 10 cans.

The olives are heated in water a short time before they are placed on the canning tables so that the women who fill the cans may handle the fruit conveniently.

The fruit is inspected by the women at the canning tables in order to detect soft or bitter fruit that may have escaped the women at the sorting table.

The cans are filled by weight in much the same manner as other fruits. A hot brine of 2½ to 3½ per cent salt, that is, 10 to 14° salometer, is added. The brine is added boiling hot in most cases from the ordinary fruit syruper or from an open pipe.

Fig. 34.—Packing pickled ripe olives in cans.

Exhausting and Sterilizing.—The filled cans are exhausted a short time, from 4 to 5 minutes, at 200 to 212°F. The center of the can should reach a temperature of at least 185°F.

The cans are sealed and are then sterilized in steam pressure retorts at 240°F. for 40 minutes. This time and temperature of processing renders the olives thoroughly sterile, and probably from the standpoint of spoilage, or possibly of *Botulinus* poisoning, the safest canned food on the market. The State Board of Health of California inspects the olive canning factories frequently and requires that every factory retain a temperature chart of each lot of olives sterilized.

If olives are packed in glass the caps on the jars tend to leak during sterilization and cooling unless the processing is carried out under heavy air pressure. If air at 15 to 20 pounds pressure is admitted to the retort with the steam and the mixture is kept in active circulation by means of open pet cocks, it is possible to sterilize olives in glass satisfactorily.

If this is not done the caps on the jars act as valves during the cooling process and allow the escape of steam, as during cooling the temperature of the atmosphere in the retort falls below that of the olives in the jars. Steam is generated violently around the pits of the olives and causes rupturing of the flesh. When the olives are later removed from the jar the fruit becomes pitted in appearance, an effect caused by atmospheric pressure over the areas above "steam pockets." However, the use of compressed air with the steam during sterilizing and cooling prevents this effect.

Summary.—The various steps in the pickling of ripe olives may be listed as follows:

1. *Receiving* fresh fruit and grading for size and into three grades for color. Grading for color, optional. Smallest fruit is sent to the oil mill.
2. *Storage* in brine (holding solution) 3 weeks or longer to harden the fruit tissue and render the action of the lye more uniform. Solution recommended, 10 per cent salt (40° salometer). Use of holding solution is optional but is strongly recommended.
3. *First lye* treatment to permit oxidation of the color. Usual concentration of first lye 1 to 1½ per cent, that is 1¼ to 2 ounces per gallon. Allowed to penetrate skin thoroughly but only short distance into flesh.
4. *Oxidation of color* by exposure to air or by aeration of water or dilute lye solutions. Period of aeration usually 3 to 4 days.
5. *Additional lye treatments* with solutions of lower concentration than first lye solution, usually ½ to 1 per cent lye, that is ½ to 1¼ ounces per gallon. There are usually two to four such additional treatments, the last of which is allowed to reach the pits of the fruit. Four such treatments with ½ per cent lye (½ ounce per gallon) are recommended.
6. *Additional aerations* of usually 24 to 36 hours' duration are given between the lye treatments listed under 5.
7. *Washing* with repeated changes of water until lye is completely removed from the flesh of the olives. Normally about 6 days' washing is necessary.
8. *Curing* in dilute brine 2 to 6 days before canning. Brine usually 2 to 4 per cent salt (8 to 16° salometer). Two days recommended.
9. *Grading and sorting for color* into light brown, dark brown and black color. Cull fruit is sent to oil mill.
10. *Canning and brining;* a hot brine of 3 to 3½ per cent salt (12 to 14° salometer) is usually added.
11. *Exhausting* at 200 to 205°F. for 4 to 6 minutes and sealing.
12. *Sterilizing* in retorts at 240°F. for 40 minutes, followed by cooling.

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CHAPTER XIII

THE CANNING OF VEGETABLES

The annual output of canned vegetables in the United States is approximately twice that of canned fruits, although the value of the canned vegetables is only slightly greater than that of the canned fruits. In 1919 the United States produced 58,000,000 cases of canned vegetables valued at $165,000,000, and 26,000,000 cases of canned fruits valued at $147,000,000.

General Comparison of Fruits and Vegetables.—In general, we may consider canned vegetables as staple foods and the higher grades of canned fruits as dessert products. Vegetables differ from fruits in chemical composition and for this reason the processes of canning differ from those used for fruits. Most vegetables contain more starch than sugar as contrasted with fruits, which are high in sugar and low in starch.

The acidity of vegetables is generally much lower than that of fruits. Vegetables are grown in or near the ground as contrasted with fruits, which are grown on trees at a considerable distance from the soil. Vegetables, therefore, usually contain more of the resistant soil organisms than fruits, and usually require more cooking than fruits to develop their most desirable flavor and texture.

For these reasons vegetables usually require a more severe processing than fruits in order to render them sterile and to cook them sufficiently for table use. Vegetables often contain disagreeable flavors or compounds which should be removed before canning, and for this reason are usually blanched before they are filled into the cans. This is not necessary with most fruits.

Vegetables are grown as annual field crops, and this makes it possible for the canner to contract for each year's supply of corn, peas or tomatoes in the current year, and to a very large degree he can plan to control the amount of his seasonal pack.

The Raw Products.—The demands of the canner have developed the varieties of vegetables most suitable for canning purposes. In general, vegetables for canning purposes should be uniform in color and quality, tender and in prime condition. Because of the rapid deterioration of vegetables after gathering, they should be transported from the field to the cannery in as short a time as possible, and for this reason the cannery should be located in or near the fields in which the vegetables are produced. This is particularly true of such quickly perishable vegetables, as corn, tomatoes, spinach and asparagus.

The cannery should arrange to plant the fields near the cannery in proper sequence, so that the produce will be delivered at a uniform rate over a long season.

Many canneries furnish the seed, or in some cases the small plants, to the growers so that they may be certain of obtaining the proper varieties for canning purposes. This is particularly desirable with tomatoes, peas and corn.

ASPARAGUS (*Asparagus officinalis*)

Most of the asparagus for canning purposes is grown in the delta lands of the Sacramento and San Joaquin valleys in California, and the largest canneries in this district operate their own asparagus fields.

Cultivation.—The delta lands are especially desirable for the culture of asparagus for the following reasons: The soil is a peaty loam, which permits the stalks of the asparagus to develop without distortion and permits them to reach large size in a short growing period. During the growing season the stalks grow from 4 to 6 inches per day. The soil is very rich and at the present time requires no fertilizing. Most of these lands are lower than the surrounding sloughs and rivers, are protected by levees, and water for irrigation is obtained by siphoning. Owing to the porous nature of the soil it may be irrigated from narrow ditches by subirrigation or lateral percolation, without the necessity of flooding the soil. This permits cultivation to obtain a light dusty mulch which protects the ground from baking and "crusting."

Harvesting.—During the first few weeks of the season the stalks are allowed to develop 4 to 6 inches above the surface of the soil and for eastern shipment are cut to a length of 10 to 12 inches.

Cutting.—Following the season of eastern shipment the fields are placed on the proper basis for the growth and harvesting of asparagus for the cannery. Asparagus for the cannery is not allowed to grow through the surface of the ground, because it is desired that the canned asparagus be white in color and if possible free from chlorophyll.

The harvesting is done by Japanese, Hindus or Portuguese who with a chisel cut the stalks to a length of about 8 to 10 inches and place the cut stalks in small piles on the ridges, from which they are gathered and placed in a box-like sled (see Fig. 35).

Washing.—The asparagus is then taken to the washing house where it is rinsed thoroughly in water and is placed in forms and cut to a length of 7 inches. The loss in cutting and sorting at the washing house is about 18 per cent.

Receiving.—The washed and cut asparagus is at once placed in small lug boxes and transported by motor boat or motor truck to the cannery. It is essential that it be canned as promptly as possible in

order that it may not become tough and bitter. At the cannery the asparagus is either taken at once to the sorting tables or is stored for a few hours in a cooled, well-ventilated room.

Inspection.—The deliveries from the different growers are carefully inspected, the amount of blemished asparagus, butts, etc., is carefully

FIG. 35.—Upper left: Lug box of asparagus as received at cannery. Upper right: Cutting asparagus for cannery. Lower: Gathering cut asparagus.

determined and the weight of the asparagus unsuitable for canning is deducted from the amount delivered by the grower. It is a common belief that California canned asparagus is artificially bleached by sulphur fun es or other chemical means, but this is not the case. The white color is obtained by cutting the asparagus before it protrudes from the ground.

Grading.—The stalks are carefully graded by hand by women, who separate the stalks into as many as 11 different grades into 3-pound boxes. The basis for grading is principally that of size, although the perfect stalks are separated from the imperfect and blemished stalks. The sizes usually made are given in Table 24.

TABLE 24.—SIZE GRADES FOR CALIFORNIA CANNED ASPARAGUS
(*After Cruess and Christie's "Laboratory Manual of Fruit and Vegetable Products"*)

Size of can	Size grade	Number of stalks per can
No. 2½ square	Giant	8–12
	Colossal	13–16
	Mammoth	17–24
No. 1 square, tips	Mammoth	21–30
No. 2½ square	Large	25–34
No. 1 square, tips	Large	31–40
No. 2½ square	Medium	35–44
No. 1 square, tips	Medium	41–60
No. 2½ square	Small	45–60
No. 1 square, tips	Small	61–80
No. 1 square, tips	Tiny	81–100

These grades are made for both the white and the green stalks; the white stalks are considered very much more desirable for canning purposes and bring a higher price.

Cutting.—The boxes for the graded asparagus are 5½ inches deep for stalks which are to be placed in No. 2½ square cans, 4 inches deep for stalks to be placed in No. 1 tall cans and 3 inches deep for the asparagus tips, which are canned in No. 1 square cans.

The boxes of graded asparagus are conveyed by a belt to a table near a rapidly revolving circular knife. A workman holds the stalks against this revolving knife to cut them to exactly the lengths given above. In some canneries all of the butts are discarded and allowed to go into the sewer or river. A few canneries shred the more tender butts and can the shredded material for soup stock.

The loss in cutting is from 50 to 75 per cent.

Peeling.—A small quantity of the very largest stalks are peeled by hand with a guarded knife similar to that used in the peeling of pears, but the demand for peeled stalks is not large.

Blanching.—Asparagus contains considerable mucus-like material and is slightly bitter. Blanching removes these materials and at the same time softens the stalks so that they may be packed more tightly in the cans and permits straightening of crooked stalks.

The blanching operation is accomplished by placing the cut stalks in large wicker baskets which are transported through a tank of boiling water. The blanching usually lasts for 3 or 4 minutes.

Filling the Cans.—The blanched asparagus is taken immediately to the filling tables, where it is placed in enamel-lined sinks in water, where women carefully sort, wash and pack it into the cans.

Square Cans.—The square can has proved the most satisfactory for the canning of asparagus for the reason that after exhausting, sealing, sterilizing and cooling, the sides of the square can are drawn in and hold the stalks tightly together. This prevents them from moving and becoming broken during shipment.

FIG. 36.—Lower: Asparagus grading tables. Upper: Retorts used in sterilizing canned asparagus.

A special can sealer is required for the sealing of these square cans on which five separate and distinct operations are used in the sealing process.

Brining.—A boiling hot dilute brine of approximately 2¼ per cent salt is added and in most cases no exhausting is necessary, although in some factories a short exhaust is given before sealing.

Sterilizing.—The sealed cans are processed for 25 to 30 minutes in steam retorts at a temperature of (in most cases) 233°F. (see Fig. 36).

Yields.—Approximately 1½ cases of 24 No. 2½ square cans each are obtained from each lug box of 50 pounds of freshly gathered asparagus. This corresponds to a yield of approximately 120 cases per acre.

GREEN BEANS (*Phaseolus vulgaris*)

Approximately 2,000,000 cases of canned string beans are produced annually in the United States. The beans should be of a deep green

color, crisp and tender, fleshy and as free from fiber and strings as possible. The Kentucky Wonder bean has proved very well adapted for canning purposes in California. The Refugee or 1,000 to 1 variety is grown successfully for this purpose in the Eastern and Middle Western States.

Picking.—The beans for canning should be less than ¼ inch in diameter and less than 3 inches long, although those ¾ inch in diameter may be used.

They are usually delivered in sacks or in slatted crates, and should not be placed in large stacks, because sweating and bacterial action may ensue with great injury to the product.

Snipping.—The beans are trimmed or snipped by hand in most canneries, although attempts have been made to use an automatic snipping machine. At present, snipping machines leave much to be desired.

Grading.—In some canneries the beans are graded for size by means of rotating cylindrical graders and in others by hand. The largest grade is cut into short lengths before canning and the small sizes are canned without cutting. The usual size grades are: first grade, $\frac{8}{64}$ of an inch in diameter; second grade, $\frac{11}{64}$; third, $\frac{14}{64}$; fourth, $\frac{18}{64}$; and the fifth grade greater than $\frac{18}{64}$ of an inch in diameter.

Blanching.—Following the snipping process the beans are thoroughly washed under vigorous sprays of water to remove adhering soil. They are then blanched either in boiling water or in steam, the period of treatment varying from 3 to 10 minutes, according to the size and maturity of the beans.

The usual blanching machine consists of a cylindrical screen equipped with a spiral conveyor, which carries the beans through boiling water. The blanched beans are cooled on a woven wire cloth conveyor under sprays of cold water, which in addition to cooling the beans, remove the slimy coating.

Canning.—The better grades of uncut beans are filled into the cans by hand, while cut beans may be filled into the cans by automatic filling machines similar to those used for peas. A brine of 2½ per cent salt is added boiling hot and the cans are exhausted for 4 to 6 minutes in live steam.

Processing.—In some canneries the beans are processed for about 20 minutes at 212°F. in an agitating cooker, after which they are placed in a retort at 240°F. for about 20 minutes. In other canneries the canned product is placed directly in the retort at 212°F. without preliminary cooking. Still other canneries sterilize the beans in boiling water or live steam for 40 to 60 minutes. The last named method of processing is probably unsafe because it is not severe enough to destroy the spores of *Bacillus botulinus*.

Yields.—Approximately 70 to 80 cases of 24 No. 2 cans are obtained per ton of beans as delivered at the cannery.

LIMA BEANS (*Phaseolus lunatus*)

Green lima beans are canned after being shelled from the pods. The bush variety is grown for canning purposes and is handled in much the same manner as peas.

Vining.—The vines are harvested when most of the beans have reached the stage of maturity most desirable for canning. The vines are passed through a pea viner, which threshes out the beans from the pods and separates the vines and pods from the beans, as described elsewhere for peas.

Grading.—The beans are cleaned in fanning mills and graded for size over screens having openings $^{24}/_{32}$, $^{30}/_{32}$, $^{31}/_{32}$ and $^{32}/_{32}$ of an inch in diameter. The various sizes are known as tiny, fancy, medium, standard and mammoth. The smallest sizes are most tender, sweetest and desirable for canning purposes.

The beans are placed in a tank of brine of such density that the green beans float and the overmature beans sink. Conveyors separate the two grades.

Before canning the overmature beans are soaked in water until plump and are canned as "soaked lima beans."

Blanching.—The green beans are blanched in boiling water in much the same manner as described elsewhere for peas. They are filled into cans by automatic fillers and dilute brine is added. The proportion of beans and brine is such that the can will be well filled after processing, due allowance being made for increase in size of the beans during cooking.

Sterilizing.—The cans require no exhaust if filled with hot beans and brine. The process is from 35 to 40 minutes at 235 to 240°F.

CARROTS (*Daucus carota*)

The pack of canned carrots is small, because this vegetable can usually be obtained fresh throughout the year. They are canned principally for soups and for restaurant use.

Small tender carrots only should be used. They are washed thoroughly and peeled in an abrading type of mechanical peeler, scraped by hand or lye peeled, the last named method being very satisfactory.

They are then diced by a special machine and canned in a dilute brine. Bitting found that a process of 240°F. for 30 minutes gave a good product.

CORN (*Zea mays*)

The canning of corn is one of the most important of the vegetable canning industries, the average annual production being approximately

12,000,000 to 14,000,000 cases, the output in 1920 being 15,040,000 cases. The most important corn canning states are Illinois, Indiana, Iowa, Maine, Maryland, Minnesota, Michigan and Wisconsin. Corn is packed in a number of other states of the Middle West and East, but very little is canned in the Southern States and none is canned on the Pacific Coast.

FIG. 37.—A typical corn cannery, husking shed in foreground. (*Courtesy, The Canning Age*).

Production Statistics.—The output of canned corn varies considerably from year to year, largely because heavy plantings follow years of high prices and light plantings follow years of low prices. Some of the variation noted in Table 25 is also due to variation in yields per acre.

TABLE 25.—PRODUCTION OF CANNED CORN 1905 TO 1921
(*After The Canning Trade Almanac*)

Year	Cases of 24 No. 2 cans	Year	Cases of 24 No. 2 cans
1905	13,018,665	1914	9,789,000
1906	9,136,960	1915	10,124,000
1907	6,654,044	1916	9,130,000
1908	6,784,000	1917	10,803,000
1909	5,787,000	1918	11,721,860
1910	10,063,000	1919	13,550,000
1911	14,337,000	1920	15,040,000
1912	13,109,000	1921	8,843,000
1913	7,283,000		

The relative packs of the more important canning states are given in Table 26.

TABLE 26.—COMPARATIVE CANNED CORN PACKS OF LEADING CORN CANNING STATES
(*After Canning Trade Almanac*)

State	Cases, 1919	Cases, 1920
Illinois	2,225,000	2,271,000
Iowa	2,496,000	3,246,000
Maine	1,652,000	1,588,000
Ohio	1,360,000	1,544,000
New York	1,014,000	829,000
Maryland	2,081,000	2,217,000
Wisconsin	635,000	590,000
Indiana	586,000	861,000
Minnesota	456,000	643,000
Missouri, Michigan, Delaware, Vermont, Pennsylvania	777,000	764,000
Other states	268,000	487,000
Total	13,550,000	15,040,000

Varieties of Corn for Canning.—Sweet corn varieties only are suitable for canning and field corn should not be used. The kernels should be sweet and tender and of good flavor and cooking quality.

Sweet corn is of two classes: one in which the kernels are arranged in regular rows, and the other in which the kernels are arranged irregularly on the cob. Stowell's Evergreen and the Country Gentleman are representative of the respective types.

The Country Gentleman variety possesses smaller kernels than the Evergreen and is generally of better canning quality.

Erwin of the Iowa Agricultural College has recently (1920) compared the yields of several leading varieties of canning corn with the results given in Table 27.

Styles and Standards of Canned Corn.—Most canned corn is packed in No. 2 cans and usually in one of two styles known in the trade as "Maine style" and "Maryland style" respectively. Maine style corn is obtained by cutting through the kernels, scraping the remaining portions of the kernels from the cobs and mixing the scrapings with the cut kernels. Enough water flavored with salt and sugar is added to give the desired consistency. The product is creamy in texture when the can is opened and is the more popular of the two styles.

TABLE 27.—COMPARATIVE YIELDS OF SEVERAL VARIETIES OF CANNING CORN
(*After Erwin*)

	Yield tons per acre		Per cent of		
	Snapped corn	Cut corn	Husks	Cob	Corn
Early varieties:					
Lambert's Early	4.97	1.48	34.9	34.0	31.1
Early Crosby	4.87	1.23	37.6	26.2	25.2
Early Evergreen	3.98	1.16	31.5	39.5	29.0
White Evergreen	4.19	1.15	32.5	40.0	27.5
Main season varieties:					
Narrow Grain Evergreen	5.02	1.47	34.7	35.6	29.2
Stowell's Evergreen	4.78	1.53	27.5	39.9	32.5
Buena Vista	4.50	1.59	38.0	36.7	35.3

Maryland style corn consists of the whole kernels cut from the cob and canned in brine, and the cobs are not scraped.

A third style is double-cut corn, from overmature corn or from large kernels obtained by cutting the corn from the cob and cutting the kernels a second time by special knives to produce a creamed corn effect.

Tentative definitions and standards for canned corn, canned sweet corn, canned sweet corn styles and canned sweet corn grades were adopted at a recent meeting by the joint committee on definitions and standards representing the Association of American Dairy, Food and Drug Officials, the Association of Official Agricultural Chemists and the United States Department of Agriculture. The definitions and standards for canned sweet corn as adopted by the joint committee are as follows:

Canned Sweet Corn.—Canned corn is the canned vegetable prepared from the grain of sweet corn (*Zea mays L.*) of the proper degree of maturity, with or without the addition of sugar and salt, and with the addition of potable water sufficient to secure the consistency proper for the product.

Canned Sweet Corn Styles and Grades.—*Cream canned corn* is canned sweet corn prepared from corn removed from the cob by cutting through the grain and subsequent scraping. It has a cream consistency.

Whole grain canned corn is canned sweet corn prepared from corn removed from the cob by cutting in such manner as to leave the grain substantially entire.

Fancy canned sweet corn is the product from young, tender corn, of superior flavor, and of such degree of maturity that the kernels are milky or creamy.

Extra standard canned sweet corn is the product prepared from corn, of good flavor, intermediate in tenderness between those used for fancy and standard grades, respectively.

Standard canned sweet corn is the product from reasonably tender corn, of acceptable flavor, the kernels of which have reached but not passed the dough state.

Substandard canned sweet corn is canned sweet corn that fails in some respects to meet the qualifications of standard grade.

The Department of Agriculture has recently ruled that the words "Maine style" may only be applied to corn grown and canned in Maine.

Some corn is canned on the cob for a special trade, but the amount so canned is very limited.

Culture and Harvesting.—Corn for canning is planted and grown in the same manner as field corn. Much of the seed corn for planting for canning purposes comes from Connecticut.

Maturity.—Corn is at its best for canning purposes only a very short time and soon passes from the sweet succulent stage to the hard, tough, starchy stage. Because corn tends to become tough and starchy rapidly, it is neccssary to observe its growth frequently and to gather it when at its optimum stage of development. Planting different fields at proper intervals permits canning over a fairly long period.

Hauling.—In harvesting the corn one man drives the wagon or truck while another snaps the ears from the stalks and throws them into the bed.

Testing Maturity.—The proper stage of maturity is judged by the appearance and feel of the ears. Recently, however, L. V. Burton[3] has developed a method of determining the maturity of canning corn, which he believes is adaptable to purposes of cannery control and as a means of testing corn from growers to insure delivery in prime condition for canning. His method consists in dropping 100 whole kernels one at a time into a brine of known specific gravity. The percentage of kernels floating at this specific gravity is determined. It is possible for a given locality and given variety of corn to establish a standard for the percentage of kernels which float and for the specific gravity of the brine.

Burton made determinations of thickness of hulls, moisture content of hulls, crude fiber of hulls and specific gravity of kernels of a large number of samples of Country Gentleman corn at different stages of maturity. He concluded that the thickness of the hulls and crude fiber in the hulls could not be used as measures of maturity. He found that the moisture content of the hulls of tough kernels was considerably below that of hulls of tender kernels. This relation is shown in Table 28.

Corn should be picked in the morning while it is cool rather than at mid-day or during the afternoon. It is then less liable to sour before husking and is more crisp and succulent than if gathered warm. It deteriorates in flavor and loses in sweetness by prolonged storage or

delay in delivery, in addition to being in danger of undergoing souring by bacterial action.

TABLE 28.—MOISTURE CONTENT OF HULLS OF COUNTRY GENTLEMAN CORN
(*After Burton*)

Grade assigned by packer	Moisture content of hulls, per cent
Fancy	72.0
Extra Standard	71.8
Fancy	70.0
Standard	67.0
Substandard	57.2

Receiving and Storage.—On arrival at the plant the load of corn is first weighed and is then driven to the dumping shed. The wagon or truck is driven onto a platform which tilts the front end upward, causing the corn to fall through a chute into a bin beneath the platform. Conveyors carry the corn from this bin to the huskers or to storage cribs. The storage floor should be enclosed to prevent trampling of the corn and should be served with conveyors which take the ears to the huskers as required (see Fig. 38).

If most satisfactory results are to be obtained the corn should be husked in the order in which it is delivered and upon the day on which it arrives at the plant. If stored in large piles it is apt to sweat and become sour through the development of bacteria. If it is to be stored overnight or longer it should be arranged in small piles to permit of good ventilation.

Husking.—Until rather recently corn was husked by hand for canning but at present hand husking is the exception, as practically all of the large canneries now use mechanical huskers.

Conveying.—The mechanical conveying systems are very complex but so arranged that the corn is handled mechanically practically throughout the entire canning process.

Huskers.—There are several designs of husking machines, but all have one feature in common. This is a pair of rapidly revolving rubber rolls against which the ear is held and which catch the husks and remove them in much the same manner that wet clothes are carried through the rolls of a clothes wringer.

The husker is equipped with a knife which cuts off the butts of the ears and also removes most of the silk with the husks. The butts drop into an apron spout at the back of the machine and thence into the husk conveyor. The husked ears pass by way of an apron spout to the clean corn conveyor for sorting and trimming.

Bins.—A convenient and efficient method of delivery of corn to the huskers is by means of a long, narrow, inclined chute connecting with a bin above the husker to the feed table at the husking machine. The operator then has at all times a supply of corn in a convenient position.

The husking machines are usually arranged in long rows and all huskers in the line deliver the husked corn to a single clean corn conveyor (see Fig. 38).

FIG. 38.—Bins and battery of corn huskers. (*Courtesy, The Canner*).

Precautions.—O. S. Sells[4] has indicated several important precautions to be observed in the operation and care of husking machines. He recommends that the butting knives should be sharpened frequently, *e.g.*, twice daily, in order that the machine may work smoothly and without excessive use of power. The rubber rolls should be properly adjusted at all times. He recommends that the rolls should be compressed ⅛ to ¼ of an inch at points of contact and more tightly compressed at the discharge end than at the feed end, since most of the husks pass through the rolls at the feed end. In order to remove the thin surface layer of oxidized hardened rubber the rolls should be dressed or roughened before the start of each season. To obtain clean husking, the machines must be supplied with ample power in order that the rolls do not stop for an instant when they first grasp the husks. A long belt is less apt to slip at this point of the husking operation than is a short belt. Because

of the heavy duty imposed upon them, all working parts must be well oiled and at the end of the season the rolls should be wrapped in paper and the machines coated with oil to check rusting and weathering.

The capacity of most single husking machines is rated at 60 to 80 ears per minute and of double machines at 120 to 160 ears per minute.

The husks and trimmings are good stock feed and are either fed direct or made into silage and used during the winter months. Conveyors carry the waste to the husk pile or to the silo.

Inspecting and Trimming.—No husker yet devised does perfect work and a certain amount of rehusking by hand and sorting is necessary to remove black ears or those with smut.

Inspection should be done while the ears rest in a single layer on a slowly moving conveyor.

Silking the Corn on the Cob.—The husking machines and trimmers remove most of the silk. In some factories the husked ears pass through a silking machine equipped with revolving brushes and rolls, and the ears are carried forward through the brushes which remove nearly all of the silk and deliver the silked ears to the washing machine. Silking of the cob can be omitted if the work of the mechanical huskers and the trimmers is well done, and removal of silk can be deferred until after cutting of the corn from the cob.

Washing.—Washing of the corn before cutting is desirable, to remove dirt, dust, ear worm excreta, smut and small pieces of husk and silk.

There are two satisfactory methods of washing: one by means of the silker-brusher washer described above, and the other by means of a revolving cylinder or conical reel, similar in design and operation to the rotary tomato washer. It consists of an inclined revolving perforated or screen cylinder through which the corn passes under heavy sprays of water. According to Sells the washer should rotate at from 12 to 15 revolutions per minute.

In tests made at the Agricultural Experiment Station at Ames, Iowa, it was found that a spray nozzle with a $\frac{3}{16}$ of an inch opening gave much better results than smaller nozzles, although more water was required. The increased efficiency, however, more than counterbalanced the increased water consumption. At 15 pounds nozzle pressure the spray was found to spread 13 inches at 18 inches below the nozzle; at 20 pounds pressure the spread was 15 inches and at 25 pounds 18 inches. Seven nozzles, the usual number per washer, will use 189 cubic feet of water per hour at 15 pounds pressure, 210 cubic feet at 20 pounds pressure and 231 cubic feet at 25 pounds pressure. At least 15 pounds pressure per square inch at the nozzle is recommended.

The silker-brusher accomplishes practically the same results as the rotary washer, but it may be followed to advantage by spraying.

If the corn is washed immediately after husking and before sorting, a great deal of the labor used in sorting can be eliminated and trimming will be facilitated, because washing removes most of the silk, pieces of husk, smut and worm evidence. In the rotary washer the ears are rubbed against each other vigorously, so that adhering dirt of all kinds is loosened and removed by the water sprays.

FIG. 39.—Cut corn cleaning machines. (*Courtesy, The Canning Age*).

Cutting.—During the early years of the corn canning industry the corn was cut from the cob by hand, an expert cutter being able to cut corn for 1,000 cans per day in this manner.

In 1882 the first mechanically operated cutter was invented by Sprague, a machine that has been improved upon but that has been the basis upon which the improved machines have been built. The knives were held under tension by rubber rings which adjusted themselves to the size of the ears but rings required frequent replacement and later were replaced by metal springs. The circular head of this machine was later replaced by feed rolls having thin steel blades to force the ears into the cutter. This improvement resulted in more uniform cutting.

In the modern machine the ears are forced through circular knives which accommodate themselves by springs to the size of the ear. Scrapers beyond the cutting knives scrape the cobs for Maine Style corn.

Two sets of knives in tandem may be used to double-cut the corn, the first pair of knives to cut about half of each kernel from the cob and the second pair to cut the remaining portion. This is done with overmature corn to improve its appearance and texture.

The corn should be fed to the cutting machines small end first, as the knives adjust themselves to the ear more satisfactorily than if the butt end enters the knives first.

The cutter knives must be sharpened frequently, under normal operating conditions once every 5 or 6 hours, special grinders being used for this purpose.

The machines should be so arranged that working parts are readily accessible for repairs. Frequent oiling is necessary for smooth operation and clean cutting.

The cobs from the cutting machines are carried by a conveyor to the husk pile or to a cob crusher, where they are crushed or cut finely enough to be mixed with the husks for use fresh, for stock feed or for siloing.

Silking the Cut Corn.—The cut corn is delivered by screw conveyors or by an elevator to the silking machine, which consists of a wire screen cylinder which acts as a sifter and of a series of wire fingers that intermesh as the corn passes through. The fingers catch and remove the silks and the screen permits the corn to pass through, but retains pieces of husk or cob.

Mixing and Cooking.—The corn from the silker is delivered by conveyor to the mixer, where it is mechanically mixed with water, salt and sugar. Water must be added in order that the corn may not become a dry, tough mass in the can, the amount used varying with the maturity, variety and method of cutting, but according to Bitting[1] will average about 5 ounces per No. 2 can. Early corn is apt to be more succulent than late corn and therefore usually requires less water. If less water is used on early corn, more salt and sugar per gallon should be added than where a relatively large amount of water is used.

Mixing must be thorough in order that the corn and brine may not separate in the can and that all cans may be alike in texture and flavor.

Brines.—Sugar and salt are added to give the desired flavor. These are dissolved in the water to give a sweet brine, which is then added to the corn in the mixer. According to Bitting, a larger proportion of sugar is used by eastern than by middle western canners but a brine made up of 200 to 300 pounds of sugar and 75 to 100 pounds of salt per 500 gallons of water may be considered as normal in composition.

Cooker-filler.—From the mixer the corn is delivered to the cooker-filler, where it is heated to 175 to 190°F. before filling into the cans.

The cooker is heated by direct steam and is equipped with a mechanical stirrer. Too much brine gives a "sloppy" can and too little a dry product. Insufficient cooking leaves the corn and brine poorly mixed, or if mixed, the two will not be properly blended.

Temperature of Filling.—Usually the cooking device also fills the can with a measured amount of corn. It has been found by experi-

ence and experiments that the best results are obtained when the corn enters the cans at 180°F. If filled at temperatures below 180°F. there will not be sufficient vacuum in the can and it will be subjected to undue strains in processing, and if filled at too high a temperature the cans may "panel," that is, be drawn in by atmospheric pressure because of the high vacuum. Filling at too high a temperature also results in a slack-filled can.

Sterilization.—Because of its high starch content and thick consistency canned corn is a very poor conductor of heat. On this account and also because of its low acidity it requires a high temperature and long period of processing.

Retorts.—Upright cylindrical retorts into which the cans are lowered in crates by means of a crane or steam hoist are generally preferred to horizontal retorts. The retorts are of smaller capacity than most horizontal retorts, which is an advantage, because it permits filling the retort quickly, thus preventing undue cooling of the canned product before the retort is filled. The usual corn retort holds approximately 900 No. 2 cans.

It is desirable that the retort be hot when the cans are placed in it, in order that cans in contact with the retort walls shall not be cooled. For the same reason the bottom of the retort should not contain cold water.

The cans should move quickly from the closing machines to the retort in order that undue cooling shall not take place before the cans enter the retort. Rough handling of the cans before or during filling of the retort should be avoided, because dented cans are apt to become leaky or buckled, with the development of "swells" or "flat sours."

Initial Temperature.—Bigelow[6] and his co-workers have proved that the initial temperature of the can contents markedly affects the sterilizing effect of a given processing time and temperature, a can with contents at a relatively low initial temperature, *e.g.*, 120°F., requiring a much longer period to reach a sterilizing temperature than a similar can with contents at a relatively high initial temperature, *e.g.*, 190°F.

According to Harrison[7] an increase of 2°F. in the initial temperature (at or about 180 to 200°F.) may be considered as equivalent to adding 1 minute to the processing time.

Time.—The usual temperature for processing corn is 245 to 250°F. At 250°F. a processing time of 70 to 75 minutes is generally used, although in some factories to insure satisfactory keeping quality 90 minutes at 245°F. is used. Bigelow recommends not less than 80 minutes at 250°F. The higher the temperature and the longer the period of processing the darker the color of the corn will be. Therefore canners are prone to process barely long enough to insure keeping of the product.

Lethal Rate.—Bigelow[6] and his associates have studied the resistance to heat of organisms causing the spoilage of corn and have based their recommendations for processing upon these data. Organism No. 26 required 214°F. for 1,180 minutes for complete destruction of all spores in corn of a PH value of 6.1. Theoretically $\frac{1}{1,180}$ of the spores were killed in one minute. Bigelow designates this as the lethal rate, which he expresses as a decimal, in this case 0.0008. As the temperature increases, the lethal rate increases. Bigelow has determined the lethal rate at various temperatures and has given in Table 29 the temperature and the lethal rate at the center of a No. 2 can of corn in a retort at 250°F. at various intervals during processing and cooling.

Column 1 gives the time elapsing from start of heating process; column 2 the temperature at the center of the can; column 3 the time that would be required to destroy the spores at the temperatures given in column 2, and column 4 the lethal rate.

TABLE 29.—LETHALITY RATE FOR NO. 2 CORN PROCESSED AT 250°F. Heating and Cooling

Indicated time, minutes	Corresponding temperature, degrees F.	Time necessary to destroy spores of Bigelow No. 26, minutes	Lethal rate
24.6	214.0	1,180.0	0.00080
29.5	220.0	756.0	0.00130
39.3	230.0	224.0	0.00456
53.0	240.0	70.0	0.01430
58.0	242.0	53.0	0.01890
64.5	244.0	42.0	0.02380
68.5	245.0	36.5	0.02740
74.0	246.0	32.0	0.03130
78.0	246.4	29.0	0.03440
78.0	246.4	29.0	0.03440
80.0	246.0	32.0	0.03130
81.5	245.0	36.5	0.02740
82.7	244.0	42.0	0.02380
84.0	242.0	53.0	0.01890
84.7	240.0	70.0	0.01430
88.1	230.0	224.0	0.00450
90.3	220.0	756.0	0.00130
91.7	214.0	1,180.0	0.00080

Similar data were obtained for other retort temperatures.

Equivalent processing times for various temperatures are given in Table 30.

TABLE 30.—EQUIVALENT PROCESSING TIMES FOR VARIOUS TEMPERATURES
(*After Bigelow*)

Process temperature in degrees F.	Time in minutes for sterilizing corn
260	56
255	64
250	78
245	96
240	129

Agitating Cookers.—With use of the agitating pressure cooker it is possible to increase the rate of heat penetration greatly and to use higher temperatures of processing than those now employed. A temperature of 260°F. has been used in an agitating cooker without injury to the color of the corn.

Retort Operation.—During the operation of retorts the bleeder valves should remain open to permit escape of air and to prevent formation of "air pockets" in which heating is imperfect because of the poor heat conductance of air. It is also desirable to heat the freshly filled retort with the safety valve or other large valve open, in order that the air may escape quickly. If one or two small cocks only are open during the period required to bring the retort to processing temperature, the pressure gauge will show a pressure due largely to entrapped air and the temperature will be considerably below that which should exist for that pressure, and the processing may be much less effective than the canner has estimated it to be. Harrison[7] reports an experiment in which the retort reached 250°F. in 4 minutes with the safety valve open, whereas 15 minutes were required with only the bleeder valves open.

The retort thermometer must be accurate if indicated processing temperatures are to be relied upon. The thermometer housing should be equipped with a bleeder cock so that the bulb is at all times surrounded by circulating steam; otherwise it may become surrounded by air and not indicate the temperature correctly.

Cooling.—The cans may be cooled in the retort by sprays of water or by repeatedly filling and emptying the retort with water.

In many corn canneries the cans are conveyed through a long shallow vat of running water either in crates or, more frequently, loosely. The retorts should be placed near the cooling tank in order that the crates of hot cans from the retorts may be emptied conveniently into the tank (see Fig. 40).

Owing to the danger from "stack burning" (scorching of the product through prolonged heating) or development of thermophilic bacteria

in cans not sufficiently cooled, it is desirable to cool the cans to 110°F. or lower.

The cooling operation exerts some sterilizing action and the higher the processing temperature the greater the sterilizing effect of cooling. If the cans are cooled rapidly the percentage of sterilization that occurs during cooling and during heating for various retort temperatures is given in Table 31.

Fig. 40.—Cooling canned corn. (*Courtesy, The Canning Age*).

Table 31.—Sterilizing Action during Heating and Cooling

(*After Bigelow*)

Retort temperature, degrees F.	Sterilizing effect during heating period, per cent	Sterilizing effect during cooling, per cent
260	56	44
255	61	39
250	78	22
245	82	18
240	88	12

Cost of Canning Corn.—The average cost of canning 86,887 cases of corn in 1920 in 21 different canneries is given by *The Canning Trade* at $1.268 per dozen. The items entering into this cost were as follows:

	Cost per Dozen	
Direct Factory Cost:		
1. Green produce	$0.324	
2. Seed loss	0.005	
3. Direct labor	0.114	
4. Cans	0.319	
5. Boxes	0.082	
6. Labels	0.017	
7. Condiments (salt and sugar)	0.065	
		0.926
Factory Overhead Expense:		
1. Factory expense	$0.131	
2. Depreciation	0.044	
		0.175
General Overhead Expense:		
1. Sales allowances and discounts	$0.024	
2. Interest and general expense	0.086	
		0.110
Brokerage and Selling Expense		$0.057
Total		$1.268

The cost of canning has decreased since 1920 but the relative costs of the different items will bear the general relation to each other given above.

Spoilage.—Canned corn may develop a black deposit due to the formation of iron sulphide, a condition favored by the presence of air. It may become "flat sour" or develop gaseous spoilage because of insufficient processing or leaks. See Chapter XIV for more complete discussion of the spoiling of canned corn.

BEETS (*Beta vulgaris*)

Beets for canning purposes must be small in size, of uniform deep red color, tender and of good flavor.

Grading.—They are usually graded for size by screens to the following size grades:

Small (Rosebuds), less than 1 inch in diameter.
Medium, 1 to 1½ inches in diameter.
Large, 1½ to 2 inches in diameter.

Those that are larger than 2 inches in diameter are cut before canning. The grader used for beets is usually cylindrical and is equipped with wooden slats set at the proper distance apart to give the above grades.

Washing and Blanching.—Beets require soaking in water and thorough washing under sprays to remove adhering soil. To permit peeling, the washed beets are steamed in a retort at 220°F. for 20 to 25 minutes. Boiling water can be used to loosen the skins but it removes considerable of the sugar and other soluble compounds.

Peeling and Canning.—The steamed beets are chilled in water and trimmed and peeled by hand. They are filled into lacquered cans by hand and a very dilute brine or water is added. In plain tin cans the color bleaches rapidly or becomes blue because of the reaction between tin salts and the color.

Processing.—Canned beets are sterilized for approximately 60 minutes at 245°F. Cut beets are packed in No. 10 cans for the use of restaurants and hotels.

OKRA (*Hibiscus esculentum*)

Okra is used principally for soups and is a staple garden crop of the Southern States where it is known in some localities as "gumbo." The pods resemble peppers in appearance and are rich in gums and probably pectin. The pods should be picked while still tender and before they have become fibrous and tough.

The pods may be blanched 1½ to 2 minutes in water, the butts cut off and discarded and the pod cut into sections crosswise with a string bean cutter. The pods may also be cut as above and canned without blanching. Bitting states that a processing of 236°F. for 30 minutes gives satisfactory results.

PEAS (*Pisum sativum*)

Peas were brought to America with the first emigrants and are now grown practically everywhere in the United States as a home garden crop and for the fresh market, but are grown even more extensively for canning.

Size of Industry.—The pack of canned peas is exceeded in normal years only by corn and tomatoes, and the value of canned peas sometimes exceeds that of corn. The canned product is relatively low in price to the consumer and is a food of attractive flavor and high nutritive value rather than a luxury.

Production.—The pack has increased from about 800,000 cases in 1885 to 12,317,000 cases in 1920.

As with corn, the production of canned peas has varied greatly from year to year according to whether the preceding year was one of under or over supply. This condition is shown in the following table.

TABLE 32.—CANNED PEA PRODUCTION
(*After Canning Trade Almanac*)

Total Production		Production by states for 1920	
Year	Cases	State	Cases
1906	4,574,608	Wisconsin	5,804,000
1907	5,885,064	New York	2,381,000
1908	5,577,000	Michigan	549,000
1909	5,048,000	Indiana	271,000
1910	4,137,000	Maryland	696,000
1911	4,372,000	Ohio	282,000
1912	7,307,000	Delaware / New Jersey	549,000
1913	8,770,000		
1914	8,847,000	Utah	595,000
1915	9,272,000	California	328,000
1916	6,686,000	Illinois	460,000
1917	9,829,053	All others	402,000
1918	11,063,156		
1919	8,685,000	Total for 1920	12,317,000
1920	12,317,000		

When high prices for peas prevail, planting and canning are stimulated, often to the point of overproduction. Provided the peas are available for canning the capacity of present pea canneries is more than sufficient to meet the normal demand.

The writer is of the opinion that more extensive advertising of canned peas and corn is required to stabilize the industry and create a healthy increase in demand. At the present time prices and production in both of these industries are subject to rather violent fluctuation.

Historical Note.—At first peas were grown garden-fashion, and picked and hulled by hand, but the cost of growing the crop and the excessive labor costs limited the output of the canneries and made the price of the product high.

Numerous attempts were made to invent mechanical hulling machines, but most of these were failures, since they were attempts to imitate mechanically the pressure exerted on the pods by the fingers. Rubber rolls, revolving discs and other machines dependent upon pressure were of very limited capacity, did not hull perfectly and bruised the peas.

In 1883 Madame Faure in France invented a machine which hulled the peas mechanically by impact. Paddles revolving in a screen cylinder broke open the pods and the peas were separated by screening. Her invention was described in *La Nature*, Paris, in 1885 and a translation of her article appeared in the *Scientific American*, June 6, 1885. Shortly

thereafter a similar machine was built in America, was proved successful at Baltimore and was rapidly adopted by commercial canneries.

Although Madame Faure's machine did the work of 100 hullers, the early American machines were somewhat larger. Scott and Chisholm were prominent in developing pea hulling machines in America.

According to R. P. Scott[10] in the season of 1886 all peas were hulled by hand; in 1887 an appreciable quantity were hulled by machinery and in 1888 one-half of the output was so hulled.

The invention of the impact huller made it possible to move canneries away from the cities to the thinly populated producing sections and thereby greatly reducing costs of production.

In 1890–1892 the hulling machine was so modified that it became possible to thresh the peas from the pods on vines, which had been cut with a mower. Previous to this it was necessary to pick the pods by hand. This advance was of nearly equal importance with Madame Faure's invention.

Today peas are grown as a field crop by tractor cultivation, harvested by mowers or pea harvesters, hauled by truck to the viner, hulled mechanically and taken at once to the cannery where they pass mechanically and more or less automatically through the operations of cleaning, blanching, filling, sterilizing and cooling.

Climatic Requirements.—A cool summer climate with frequent rains or cloudy or foggy weather produces peas that are tender, sweet and of good color. Wisconsin is the premier pea-producing state, largely because of the favorable climatic and soil conditions.

At present New York and Wisconsin furnish 60 per cent of the entire pack, although Utah and the uplands of Colorado are also very suitable for peas.

Varieties.—Field peas have been classified as a different species from garden peas, but this distinction is being abandoned. Formerly field peas were classified as *Pisum arvense* and garden peas as *Pisum sativum.* At present both are classified as *Pisum sativum.*

For canning purposes, Shoemaker[11] lists the following requirements: (1) The variety must be productive, a requirement which excludes dwarf types and includes the quality of hardiness. (2) All plants must ripen uniformly. (3) All pods on each vine must be in usable condition at one time; that is, none must be too ripe or too immature. This requirement excludes varieties with too great length of vine. Bush vines, not climbing vines, are used. (4) The peas must remain green after processing, which eliminates yellow-seeded varieties. (5) High quality, *i.e.*, good flavor, texture and small size are necessary.

The viner has made requirements (2) and (3) important. When the pods were gathered and hulled by hand, uniformity in ripening was not so necessary.

Peas for canning purposes are of two types, namely, the early smooth-seeded varieties and the later and sweet, wrinkled-seeded varieties. The latter are of better flavor, but often do not produce as heavily as the smooth-seeded types. The most important smooth-seeded variety is the Alaska and the most widely used wrinkled-seeded varieties, the Horsford Market Garden, Advancer and Admiral.

The Food Administration in 1917 compiled data showing the relative importance of the different varieties as follows:

Type	Per Cent of Total Production
Smooth peas:	
1. Alaska	55
Wrinkled peas:	
1. Horsford Market Garden	28
2. Advancer	18
3. Little Gem	1
4. Perfection (Davis)	1
5. Admiral	13
6. Surprise	2
7. All others	2

The Alaska is a favorite with canners, because it is hardier and a more reliable producer than most of the wrinkled varieties. For this reason it is about the only variety used in the southern areas of the pea canning region, including Maryland, Delaware, New Jersey and the southern parts of Ohio, Indiana and Illinois. This variety ripens early and retains its deep green color well in processing.

Harvesting.—The time of harvesting is determined largely by the appearance of the pods, which should be swollen and well filled with young succul nt peas and changing in color from dark to light green.

The fields should be inspected before harvesting to remove vines of "off type."

The cannery agent sets the date of harvesting and frequent inspection is necessary to make certain that the peas do not pass prime condition and become overmature.

An ordinary mower equipped with vine-lifting guards attached to the cutter bar and a swather which bunches the vines in a neat windrow is used. The vines may be loaded direct from the windrow onto wagons or the rows may be bunched with a rake. In some cases automatic loaders drawn by a tractor can be used to load the wagons.

To avoid wilting it is desirable to cut the vines in the morning or evening rather than in the middle of the day. Delay in vining results in deterioration in quality and may permit sweating and fermentation.

Vining.—Most of the shelling or vining is done at so-called vining stations, located in the fields. This avoids long haulage of the vines.

The vining machine consists of a perforated metal cylinder, inside of which are beaters on a central shaft. The cylinder revolves slowly, while the beaters revolve rapidly in the direction opposite to that of the cylinder. The peas are hulled by impact with the beaters and fall through the openings in the cylinder. The vines are carried through the

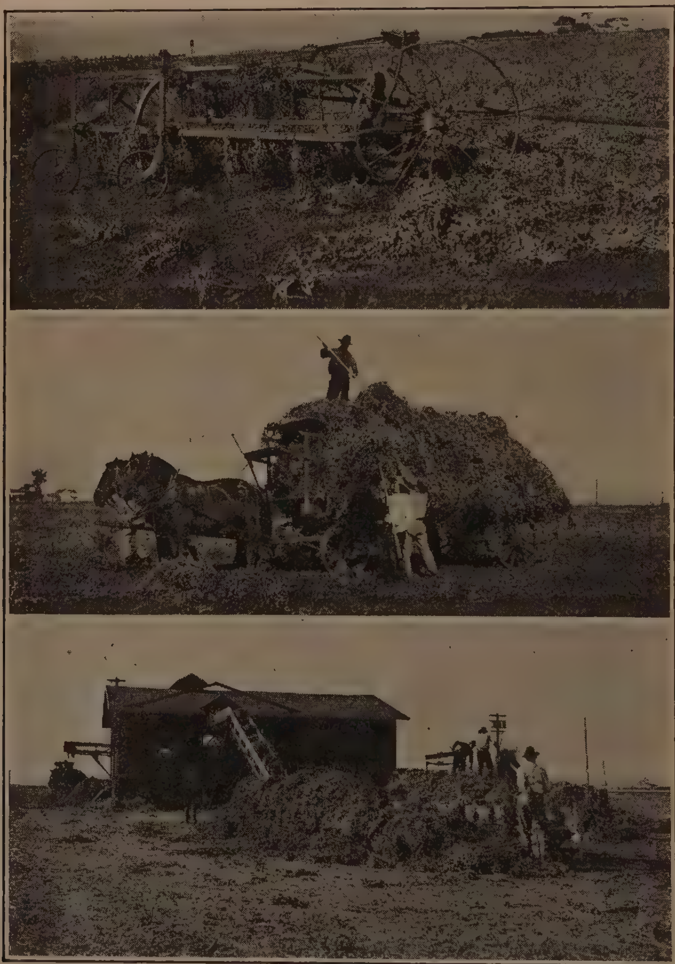

Fig. 41.—Harvesting peas in California. Upper: Rake used in bunching cut vines. Middle: Hauling pea vines to vining station. Lower: Vining station.

cylinder and are delivered to a conveyor, which delivers them to a wagon or to a silo. The beaters are pitched at such an angle that the vines are carried through the cylinder and the speed of the beaters and the pitch determine the time the vines remain in the viner. The peas drop through the perforated cylinder onto a slowly upward moving canvas

belt to which leaves and pieces of pod stick while the peas roll down the belt into hoppers (see Fig. 42).

One viner is required for each 100 acres under average conditions. According to recommendations of the A. K. Robbins Machinery Company three viners will supply peas for one cleaner, one blancher, one filler, two closing machines and five 40 by 72 vertical retorts.

Fig. 42.—Pea viner. (*Courtesy, The Canning Age*).

Yields.—The yield of shelled peas varies from nothing to 5,000 pounds per acre, but the average for the United States for the 4 years, 1917–1920, was 1,800 pounds.

Cleaning.—At the factory the peas are first passed through a cleaner, which removes light pieces of pods or vine by a blast of air. The air-cleaned peas drop on to a large screen, which removes large pieces of pod, etc., and thence to a fine screen, which permits passage of fine dirt and splits but retains the whole peas.

In California is used a bur cleaner, consisting of a revolving carpet-covered roller to which clover burs stick. Thistles may be removed by flotation in water and skimming.

Size Grading.—The cleaned peas are graded for size through a long cylinder or through a series of nested cylinders having holes of the diameters given below. In the single-cylinder grader the smallest peas are removed first and in the concentric or nested grader the largest sizes are removed first.

Grade No.	Screen
1. Petite	$\frac{9}{32}$ of an inch diameter
2. Extra Sifted	$\frac{10}{32}$ of an inch diameter
3. Sifted	$\frac{11}{32}$ of an inch diameter
4. Early June	$\frac{12}{32}$ of an inch diameter
5. Marrowfats	$\frac{13}{32}$ of an inch diameter
6. Telephone	larger than $\frac{13}{32}$ of an inch in diameter.

Quality Grading.—In addition to grading for size the peas are also graded for quality. If the peas are placed in a tank of brine of the proper specific gravity those of higher quality will float and the starchy or inferior peas will sink. This separation is accomplished in automatic grading machines consisting of two tanks of brine through which the peas are carried by conveyors. According to Bitting the first tank is usually filled with brine of specific gravity of 1.04 and the second tank with a brine of a specific gravity of 1.07. The peas that float in tank No. 1 are known as Fancy and those which float in tank No. 2 are known as Standards. Those which sink in tank No. 2 are known as Seconds, or Substandards. There is a large percentage of Seconds among the larger sizes of peas, while most of the very small peas are of the Fancy grade.

Because of their high sugar content and deep green color, the small peas command the highest prices. On account of their high starch content the larger peas tend to produce a cloudy liquor, in addition to being less desirable in flavor and color. However, they are of lower moisture content and higher nutritive value.

Effect of Maturity.—If the peas are carefully grown and harvested at the proper stage of maturity, the percentage of large sizes will be low, although the yield per acre will not be as great as if the peas are allowed to reach a more advanced stage of maturity. Therefore, the canner must exercise great care in supervising the harvesting of the crop so that the growers will not allow the peas to become too ripe. The tendency on the part of the grower is to permit the vines to reach a more advanced stage before harvesting than the canner desires, in order to obtain the maximum yield.

Under normal conditions from 60 to 70 per cent of the peas will fall within the third and fourth grades, about 15 per cent in the first two grades and the remainder in the fifth and sixth grades.

Sorting.—Following the mechanical grading operations the peas are carefully sorted on broad belts to remove pieces of pod, etc.

Blanching.—Peas are blanched thoroughly to fix the color, to remove mucus from the skins, to improve the flavor and to permit the placing of a larger weight of peas in the can.

The length of blanching varies greatly with the maturity of the peas and may be as short as ½ minute for very small, tender peas and as long as 30 minutes for large, starchy peas. Bigelow[13] states that blanching

does not soften overmature peas, but on the contrary hardens them.

If the peas have soured slightly between the shelling and the blanching processes it is desirable to add a very small amount of sodium bicarbonate to the blanching tank. Some canners believe that the addition of a small amount of soda intensifies the green color and that it should be used for the peas whether sound or sour in condition, but its use is not general.

FIG. 43.—Pea blanchers. Roach Cannery, Michigan. (*Courtesy, The Canner*).

The usual pea-blanching machine is continuous in operation and consists of a screen or perforated cylinder with a spiral conveyor, which revolves in a tank of boiling water. The length of blanching is regulated by the speed of rotation (see Fig. 43).

The blanching water should be changed frequently in order that it may not become foul.

Washing.—The peas should be washed very thoroughly after blanching. The usual washer is a revolving screen cylinder with internal sprays.

Filling.—The peas are filled into the cans by automatic machines which deliver a definite volume per can. Generally, the peas are heated just before they enter the filling machine, a boiling hot brine is added and the exhausting of the cans is not necessary. In most cases the brine used in the canning of peas consists of a mixture of salt, sugar and water. About 2 per cent of salt is used and to the better grades from 2 to 5 per cent of sugar is frequently added. In a California cannery a brine of 22½ pounds of sugar and 18 pounds of salt per 150

gallons of water was used for the best grades, and one of 31½ pounds of salt per 150 gallons for the poorer grades. A filling machine is shown in Fig. 44.

Storage.—If unblanched peas are not canned at once they should be stored under dilute brine or water to avoid darkening and growth of bacteria.

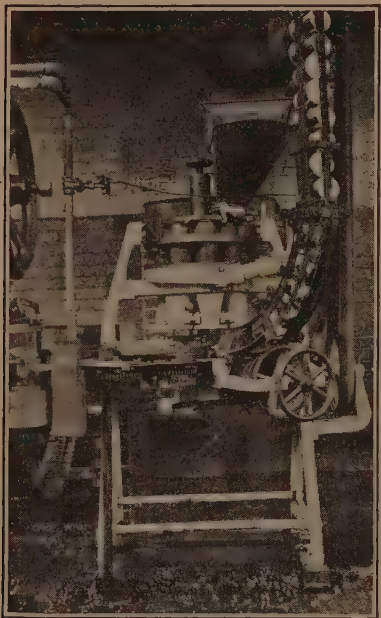

FIG. 44.—Can filling machine for peas.

Sterilizing.—Large, starchy peas require a longer process than the small, tender grades. At 240°F. 35 minutes is usually regarded as a safe sterilizing schedule, although Bigelow[13] recommends 40 minutes at 240°F. and 15 minutes at 250°F. for No. 2 cans and 50 minutes at 240°F. or 20 minutes at 250°F. for No. 10 cans. Considerable losses from spore-bearing anaerobic bacteria have been encountered by the canners of peas in the Middle Western States. At the present time, however, sterilization processes are usually severe enough to destroy these organisms.

Cooling.—Cooling should be thorough and rapid following sterilization, to avoid excessive softening and the formation of a cloudy brine through gelatinization of starch.

Cut-out Standards.—The normal net contents of a No. 2 can of peas is 21 ounces, of which usually slightly more than 13 ounces consists of peas and 7 ounces of liquid. The Bureau of Chemistry, U. S. Department of Agriculture, has ruled that a No. 2 can must contain 13.5 ounces drained weight of peas.

Spoilage.—For discussion of spoilage see Chapter XIV.

Causes for Substandard Peas.—The canner desires to obtain the largest possible proportion of the best grades of peas, because therein lies the most profit. Bigelow[13] has summarized the causes for substandard or low-grade canned peas in a recent article as follows:

1. The use of a variety which does not ripen evenly, or of peas that have not been properly "rogued."
2. Lack of care as to time of harvesting, permitting too many peas to become overmature.
3. Allowing vines to stand too long after mowing, causing peas to ripen and harden.

4. Allowing peas to remain too long in boxes after being vined, caused by delay in hauling from viner or delay at factory.

5. Mixing of mature and immature peas in grading. During processing the mature peas swell and cause the pack to appear ungraded.

6. Permitting heating of the vines or hulled peas.

7. Excessive handling of unblanched peas, particularly in boxes. Smooth, perforated metal pails are preferable to boxes.

8. Underfilling or overfilling through lack of proper adjustment of the filling machine.

9. Improper cooling, injures color and gives cloudy brine.

10. Use of hard water in blanching. Causes peas to be hard.

11. Too strong brine. This causes toughness.

12. Too long blanch. Causes peas to be hard, contrary to popular belief—blanching does not make peas tender. Tenderness is imparted only in the processing.

13. Lack of judgment in varying the process to suit the character of the raw material.

Cost of Canning Peas.—The average cost of canning peas in 11 plants in Wisconsin and Illinois in 1921 is given as follows by A. T. Bacon:[14]

Average Unit Cost to Pack 1 Dozen No. 2 Cans of Peas, 1921

Direct Factory Cost:	
Green Produce (including seed)	$0.379
Direct Labor	0.113
Cans	0.302
Boxes	0.074
Labels	0.022
Condiments	0.022
Total	$0.912
Factory Overhead:	
Depreciation	0.053
Factory Expense	0.138
Interest	0.023
Insurance	0.013
Total	$0.227
Selling Expense:	
Brokerage and Commission	0.038
Sales Allowances and Selling Expense	0.011
Discount allowed	0.019
Total	$0.068
General Expense:	
Administrative and Clerical Salaries (portion)	0.048
Miscellaneous General Expense	0.016
Total	$0.064
Grand Total	$1.271

PIMIENTOES

Pimientoes, large, red, smooth, sweet, bell peppers, are canned extensively in the southern part of California and Georgia. They are successfully grown in many of the Southern States and it is probable that commercial canning of this vegetable will extend to these states. They are also canned commercially in Spain and the Spanish product competes with the product from California and Georgia.

Pimientoes for canning purposes should be large, smooth-skinned (not wrinkled), deep red in color and sweet in flavor.

Peeling.—The most satisfactory process of peeling consists in roasting the pimientoes until the skin may be easily slipped from the flesh and is accomplished by passing the pimientoes through a slowly rotating iron cylinder heated by gas flames. The rate of rotation is approximately 12 revolutions per minute and the pimientoes are heated for about 1 minute. They then go to the peeling tables where the skins are slipped from them by hand. The cores and stems are removed at the same time by a knife similar in construction to a peach pitting spoon. The roasting not only removes the peels but softens the flesh of the pimientoes so that they may be flattened and packed tightly into cans.

In another peeling process in common use the pimientoes are heated in a vat of cottonseed oil at a temperature of about 400°F. for about 3 or 4 minutes, which accomplishes practically the same result as the roasting process, although it is claimed that roasting imparts a desirable flavor which cannot be obtained by the oil peeling process.

Pimientoes may be peeled with boiling lye but lye peeling is not considered as satisfactory as other methods.

Canning and Sterilizing.—The perfect specimens are packed carefully by hand into small cans or jars and usually no liquor is added. In this respect pimientoes resemble "solid-pack" tomatoes. In some canneries a small amount of water or dilute brine is added. Because of the solid consistency of the pack it is necessary to exhaust the cans very thoroughly, preferably 12 to 15 minutes at 200 to 212°F. The cans are sterilized in boiling water for about 30 minutes.

RHUBARB (*Rheum rhaponticum*)

Rhubarb more nearly resembles a fruit than a vegetable in composition. On account of its high acidity it attacks tin plate vigorously and perforation of cans is common.

The rhubarb is washed, cut in short lengths and is either packed at once into cans with water, or is cooked a short time in a jelly kettle and packed hot into cans, the latter method being preferable because it gives a better filled can.

The process is about 13 minutes at 212°F.

PUMPKIN (*Cucurbita pepo.*)

Canned pumpkin has made pumpkin pie available at all seasons of the year and pumpkin canning has become an important industry.

Pumpkins for canning should be of the hard, sweet varieties, evenly ripened, and the flesh should be of good texture, golden yellow, but not watery.

Pumpkin is canned late in the fall after the season for tomatoes has closed.

The pumpkins are washed and stemmed, cut in pieces by large knives or hatchets or by special roller discs and the pieces are washed in a revolving circular screen ("squirrel cage") washer to remove seeds and fiber, or this material is removed by a revolving, blunt, broad cone against which the halved pumpkin is held by hand.

The pieces are then steamed in retorts at 240°F. for 20 minutes until the pumpkin is well softened or in a rotary steam cooker designed for the purpose.

The pulp is separated from the skin and tough fiber by a heavy tomato pulper and the pulp so obtained is evaporated in open kettles to a heavy density and canned hot as a solid pack. Enamel-lined cans should be used to prevent darkening of the product.

No exhaust is necessary. The process is usually conducted at 250°F. for 90 minutes, heat penetration being extremely slow because of the heavy consistency of the pumpkin.

A good can of pumpkin should be smooth, evenly screened, free from fiber and uniformly colored. When opened the can should be filled to within ½ inch of the top.

SPINACH (*Spinacea oleracea*)

The commercial canning of spinach has been a recent development of the canning industry, but this article is increasing very rapidly in popularity and the size of the pack is increasing at a corresponding rate.

Culture and Harvesting.—The spinach seed is planted in drill rows, preferably in light sandy soil. There are two crops per year, a spring crop and a fall crop. The spring crop is the more important one, and it is harvested by hand by cutting the plant close to the ground. The leaves are placed in lug boxes or in sacks for transportation to the cannery.

Spinach deteriorates very rapidly after cutting and particularly so if placed in large piles or in a warm room, consequently it must be canned as promptly as possible.

The floor on which the spinach is placed before canning should be well ventilated, and, if it is not possible to can it at once, it should be mixed frequently by shoveling.

Cutting and Sorting.—The spinach is delivered to the cutting tables in lug boxes which hold about 26 pounds each. The stems and defective leaves are removed by hand.

Washing and Blanching.—Spinach must be subjected to a very thorough washing process to remove soil and insects. The usual washer consists of a long inclined perforated metal cylinder, in which the leaves are agitated and heavily sprayed with water.

Following the washing process the spinach is again sorted and is then blanched for about 6 minutes to fix the color and to soften the leaves so that they may be packed tightly into the cans.

The blancher consists of a rotating screen cylinder which carries the spinach through hot water, the temperature of which is varied according to the tenderness of the product. For example, a temperature of 185°F. may be used for small tender leaves, 200°F. for medium and 212°F. for tough leaves.

Following blanching, the spinach is again inspected, sorted and washed under sprays of cold water.

Canning and Sterilizing.—The spinach is filled into cans by hand and is pressed tightly into the cans by means of a cylindrical wooden plunger. The water is drained from the can and a hole is punched in the center of the packed spinach by means of a wooden dagger. Dilute brine containing 3½ per cent salt is filled into this opening. No. 10 cans of spinach are exhausted from 10 to 12 minutes, smaller cans for 6 minutes at approximately 200°F. Some canners insert a steam jet into the center of the packed can for a few seconds to aid exhausting.

Sterilizing is severe for the reason that the solidly packed spinach is a very poor conveyor of heat. In California the State Board of Health requires that No. 2½ cans be sterilized at 247°F. for 70 minutes, or at 252°F. for 50 minutes and that No. 10 cans be sterilized at 247°F. for 110 minutes, or at 252°F. for 90 minutes, when the centers of the cans are at 180°F. when they enter the retort. Bigelow has shown that if less spinach is packed into the cans, and the contents therefore more fluid in nature, penetration is very much more rapid.

The present cut-out weights are: for No. 2 cans, 13 ounces; for No. 2½ cans, 19 ounces; for No. 3 cans, 21.5 ounces; and for No. 10 cans, 66 ounces.

Effect of Initial Temperatures.—As a result of investigations on the heat penetration of spinach and the death temperature of heat-resistant, spore-bearing bacteria by K. F. Meyer, A. C. Richardson and J. R. Esty, the California State Board of Health has established the following times and temperatures for No. 2½ and No. 10 cans of spinach when the centers of the cans register the temperatures given in column 1.

TABLE 33.—PROCESSING TIME FOR SPINACH AT 252°F.
(Based on a basic time of 50 minutes for No. 2½ and 90 minutes for No. 10 cans and 180°F. for temperature of can entering retort)
(*After K. F. Meyer*)

Temp. of can entering retort, degrees F.	Add minutes	Total cook	
		No. 2½ cans	No. 10 cans
120–122	20	70	110
122–125	19	69	109
125–128	18	68	108
128–131	17	67	107
131–134	16	66	106
134–137	15	65	105
137–140	14	64	104
140–143	13	63	103
143–146	12	62	102
146–149	11	61	101
149–152	10	60	100
152–155	9	59	99
155–158	8	58	98
158–161	7	57	97
161–164	6	56	96
164–167	5	55	95
167–170	4	54	94
170–173	3	53	93
173–176	2	52	92
176–179	1	51	91
179–182	0	50	90
	Subtract Minutes		
182–185	1	49	89
186–192	2	48	88
193–199	3	47	87
200–206	4	46	86
207–209	5	45	85

The ruling was made to preclude danger of botulism from commercially canned spinach.

Yields.—The loss in trimming and sorting is from 30 to 40 per cent and the yield in California is approximately 35 cases of No. 2½ cans per ton of fresh spinach as delivered at the cannery.

SWEET POTATOES (*Ipomoea batatas*)

The present annual pack of sweet potatoes is about 1,000,000 cases and is valued at about $4,000,000. The potatoes are canned during October, November, December and January, when the canning plants are not in use for other vegetables and most of the canning is done in the Southern States.

Varieties.—Two types are used for canning, namely, the yellow or Jersey type, grown in Delaware, New Jersey, Maryland and Virginia, and the white type, grown further south. Because of its yellow color the Jersey is preferred for canning. The Jersey is not as sweet as the white varieties but it is of good flavor and cooking quality.

Steaming.—The potatoes are washed and placed in crates in a retort at 240°F. for 9 to 12 minutes to soften and loosen the skins. A quick, high heating is better for the purpose than a longer cook at a lower temperature.

Peeling.—The steamed potatoes are taken at once to the peeling tables where workers with heavy canvas gloves slip the skins from the potatoes. If properly steamed, the skins slip from the potatoes readily. The potatoes do not peel satisfactorily if they have been allowed to stand so long after digging that they have become shriveled.

Sweet potatoes are also peeled by use of the lye peach-peeling machines described elsewhere but a stronger lye solution and longer lye treatment are required than for peaches. Revolving brushes are used in addition to water sprays to remove the lye-softened skins. Hand trimming is usually necessary with lye-peeled potatoes.

Abrading machines, such as those used for carrots, can be used for sweet potatoes, although the waste in peeling is high and considerable hand trimming is required.

Lye-peeled potatoes or those peeled by machines are steamed to soften them before packing.

Packing and Sterilizing.—The hot peeled potatoes are tightly packed at once into sanitary cans with the addition usually of a small amount of water. The cans are heaped full and the potatoes are pressed in tightly.

A long exhaust is desirable, because the solid-packed potatoes conduct heat very slowly. Bitting recommends 18 minutes at 185 to 200°F.

The sealed cans are sterilized 3 to 4 hours at 212°F. or at 240°F. for about 70 minutes. The lower temperature yields a product of lighter color and better flavor.

Darkening and "Springers."—Overfilled cans become "springers" and although wholesome, are not purchased because of their bulged appearance.

Potatoes in slack-filled or insufficiently exhausted cans may blacken, a condition caused by solution of iron, its oxidation to the ferric condition and its combination with tannin of the potato.

TOMATOES (*Lycopersicum esculentum*)

According to Bitting, the first record of the canning of tomatoes is of that done by Harrison W. Christy in 1847 at Jamesburg, N. J. Toma-

toes are now used in enormous quantities in the fresh state, as canned tomatoes and in the form of puree, paste and various relishes, such as ketchup, chili sauce, etc.

Importance of the Industry.—Tomatoes have usually headed the list of canned fruits and vegetables in quantity, although in recent years they have occasionally been exceeded by corn or peas.

Worsham[16] has studied the data for production and consumption of tomatoes and has arrived at the conclusion that the consumption of canned tomatoes is decreasing. He attributes this decrease to the importation of tomatoes during the winter and spring from Mexico and the southern United States and to the increase of home gardening with consequent increase in the home canning of tomatoes. It is possible also that the general sale of low-grade canned tomatoes a few years ago did much to destroy the confidence of the public in the product.

Table 34 gives the comparative production of tomatoes, peas and corn since 1907.

Table 34.—Comparative Production in the United States of Canned Tomatoes, Peas and Corn

(Tomatoes in cases of 24 No. 3 cans each and peas and corn in cases of 24 No. 2 cans each)

Year	Tomatoes, cases	Peas, cases	Corn, cases
1907	12,918,206	5,885,064	665,044
1909	10,984,200	5,028,000	5,787,000
1911	9,749,000	4,532,000	14,337,000
1913	14,206,000	8,770,000	7,283,000
1915	8,469,000	9,272,000	10,124,000
1917	15,076,000	9,829,153	10,803,015
1919	10,809,000	8,685,000	13,550,000
1920	11,368,000	12,317,000	15,040,000

It will be noted that the packs of all three vegetables have been subject to large fluctuations from year to year.

Varieties of Tomatoes for Canning.—Tomatoes for canning should be moderately large, smooth, so that peeling can be easily accomplished, evenly ripened to the stems, of a clear red color and possessing a large proportion of solid meat of good flavor. Those of irregular shape and wrinkled skins are difficult to peel and the loss in preparation is excessive. Some varieties possess large seed cavities and on this account soften badly in the can, giving an unattractive appearance and a slack-filled can. Soft, watery varieties are objectionable for similar reasons. Yellow and purple tomatoes are not desirable; a deep, uniform red color is the ideal. Lack of uniformity in ripening excludes some varieties for canning.

Not only must the tomato possess desirable canning qualities but it also must yield well to be grown profitably. Early ripening, therefore, is desirable, since yield is largely influenced by the length of the picking season.

Seedsmen and others have developed a number of excellent strains of tomatoes for canning purposes. Of these, the Stone is perhaps the best known and most widely grown. It is a medium large, smooth-skinned, bright-red tomato with a large proportion of solid meat. It is a regular bearer but ripens over a comparatively short season.

The San José Canner is popular in California. It is a large tomato of rather irregular outline and is somewhat flattened vertically. It is a heavy bearer and ripens over a long period, but many canners believe its form and color could be improved by breeding experiments.

The Matchless is grown extensively in Delaware and Maryland. It is oblate in form in vertical section and circular in horizontal section. It is of large size and relatively free from corrugations and the flesh is firm and of reddish-pink color. The pulp around the seed cavity is yellowish-red. It ripens rather late and is claimed to be a more irregular bearer than the Stone.

The Paragon is a large flattened, solid, bright-red tomato of good canning quality and early ripening, and has a tendency to develop prominent ribs.

The Landreth is an excellent canning variety. Other canning varieties grown commercially are the Coreless, Perfection, Greater Baltimore, Favorite, Red Rock and Success. The Perfection is an early variety and the Coreless one of the best late ripening varieties.

Propagation.—Canners have found by experience that it is desirable for the canners themselves to propagate the young plants in hot beds and cold frames in order that the proper varieties shall be grown. When the purchase or propagation of young plants is left to the choice of the growers, the cannery will usually receive several varieties, of varying canning quality.

Picking and Transportation.—The picking season varies with the locality. In California, picking for canning purposes usually begins about Aug. 5 to 10 and continues until about Dec. 1. In Maryland the season is approximately from Aug. 20 to Oct. 20; in Indiana, Aug. 1 to Nov. 1; and in some of the Southern States from about July 15 to about Oct. 15.

Tomatoes for canning must be prime ripe, without green areas around the stem end and not over-ripe. In order to secure tomatoes in this condition the fruit must be gathered every day or every other day; otherwise a great deal of it will become over-ripe.

Shallow boxes are to be preferred to deep baskets or deep boxes. The tomatoes in the bottom of a deep container are subjected to con-

siderable pressure and may become crushed or cracked during transit. Boxes should be provided with cleats across the ends to prevent crushing, when the boxes are piled one above the other, and to provide ventilation between the boxes.

Tomatoes should not be allowed to stand in the fields in the sun after picking, because this will cause over-ripening and development of microorganisms, but should be transported to the cannery as promptly as possible and without undue bruising or crushing in transit.

Sampling at Factory.—At the factory, immediately on delivery, a representative sample should be taken by the canner and the proportions of prime fruit, rotten fruit and green fruit determined. This can be done by dumping one or two boxes, taken at random, into a tank of water and sorting the sample carefully. The grower can then be paid for the fruit which is suitable for canning purposes and "docked" for rotten and green fruit. By no other means is it possible to maintain a delivery of desirable fruit and reduce to a minimum the delivery of unfit material. Particularly is this true near the end of the season when early fall rains have damaged a large proportion of the crop.

Storage at Cannery.—Tomatoes deteriorate rapidly after delivery and should be canned as promptly as possible.

Washing Empty Boxes.—Under the best conditions picking boxes become contaminated with mold, yeast and bacteria which develop in tomato juice or pieces of pulp on the bottoms and sides of the boxes. Therefore, boxes should be thoroughly washed and steamed at the cannery before return to the grower.

Washing.—Although the washing of tomatoes for canning is not as important as for the manufacture of tomato pulp, nevertheless, it is often desirable to wash the fruit before scalding. This is especially true after rains and where the fruit may have been grown in close proximity to wet clay soil.

Washers.—The most efficient washer for tomatoes consists of an inclined perforated metal drum screen fitted on the inside with longitudinal corrugations or a spiral conveyor. The tomatoes rub against each other as they traverse the cylinder and are subjected to heavy sprays of water. The rubbing softens the dirt and the sprays remove it (see Fig. 10).

Another common type of washer is that known as the apron washer. The tomatoes are carried on a door matting conveying belt beneath sprays of water. Sprays may also be played against the tomatoes from below the belt with good effect. This washer is less liable to break or bruise tomatoes for canning. Simply allowing the tomatoes to pass through a tank of water adjacent to the scalding machine usually does not remove the dirt effectively.

Testing.—The effectiveness of the washing process can be determined by allowing some of the tomatoes to dry in the air after washing. If they have not been thoroughly washed a film of dirt will be evident on the dried fruit. The water used in washing must be renewed frequently, otherwise it may add more dirt to the tomatoes than it removes.

Sorting and Trimming.—In the canning of tomatoes in the majority of plants the peelers do most of the sorting. However, sorting can be more efficiently and satisfactorily done by a few sorters than by a number of peelers. Peelers are apt to be more careless in the sorting of the tomatoes and are particularly liable to throw rotten fruit and other unfit material into the bucket containing peels and cores for pulping. If the washed tomatoes are very carefully sorted in such manner that only the large perfect fruit goes to the scalder, the rotten fruit to the dump and the small and misshapen fruit to the pulping line, sorting will be a very profitable investment. Only the best tomatoes should be used for canning. Small, badly wrinkled, unevenly ripened and over-ripened fruit should be used only for pulp.

Tomatoes that carry a small amount of rot or green areas may often be trimmed and used for canning as standard grade.

In sorting and trimming, the tomatoes are carried on a broad belt or woven metal conveyor before the sorters. For effective sorting the belt should move at a rate not to exceed 25 feet per minute and, according to B. J. Howard,[15] it should be equipped with turning devices at regular intervals, as experience has shown that the sorters otherwise allow many of the tomatoes to pass without turning, thus permitting unfit fruit to pass to the peeling tables.

Scalding.—Tomatoes are scalded sufficiently to loosen the skin but not so long that the pulp and flesh become softened or the tomatoes thoroughly heated. The scalding is accomplished by conveying the tomatoes through boiling water or live steam. Very often the same conveyor that carries the tomatoes before the sorters carries them through the steam scalder, which in this instance is merely an enclosed sheet metal box filled with sprays of live steam.

The tomatoes are exposed to the live steam or boiling water from ¼ to 1 minute, depending upon their condition. As they emerge from the scalder they are subjected to sprays of cold water or are immersed in cold water to check further cooking and to crack the skins (see Fig. 45).

Hand Peeling.—The scalded tomatoes are delivered by conveyor or in dishpans or buckets carried on belts to the peeling tables where they are peeled by hand. The pans should not be deep, in order to avoid continued cooking or crushing. Prompt peeling is essential in order to avoid incipient spoilage.

The tomato is peeled by first pulling the skin back from the blossom end with the blade of a short coring and peeling knife. The operation

is completed by removing the core with the point of the knife, which is directed toward the center of the tomato to avoid opening the seed cavity. A knife commonly used for this operation is spoon-shaped. Green and otherwise undesirable spots are removed by the peelers.

The peeled tomatoes are usually placed in broad pans or buckets and are conveyed by a belt to the canning tables and the sound cores and peels are usually placed in buckets or on a belt and sent to the pulping machines for the manufacture of low-grade puree, which is used for addition to standard-pack tomatoes or for low-grade ketchup, etc. Unfit trimmings and rotten material are discarded. Great care must be taken at the peeling tables so that rotten fruit does not find its way into the pulp stock.

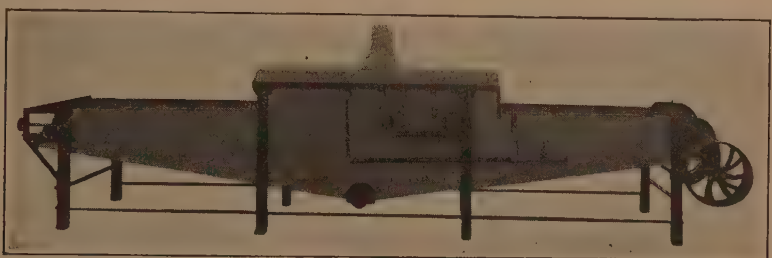

FIG. 45.—Tomato scalder. (*Courtesy, Anderson-Barngrover Mfg. Company*).

Pans, buckets, conveyors, floors and all machinery used in the handling and treating of tomatoes should be frequently washed. A clean plant encourages cleanliness and care on the part of the employees and will improve the quality of the pack.

The loss in peeling varies from about 40 to about 60 per cent, but much of this material is often utilized for the production of puree.

Lye Peeling.—A machine has recently been invented by H. M. Miller, which peels the tomatoes mechanically after treatment in dilute boiling lye solution.

Solid Pack.—The whole, firm, evenly colored tomatoes are packed carefully by hand into cans without the addition of juice or puree and are known as "solid-pack" tomatoes. There is danger of overfilling, a condition which will result in the development of "flippers" or "springers" and cause the product to be unsalable, although perfectly wholesome.

Some canners add to each can of the highest grade of tomatoes a level teaspoonful of an equal mixture of salt and sugar in order to improve the flavor.

Standard Pack.—Standard-pack tomatoes consist of the small tomatoes, those of imperfect color, soft tomatoes and trimmed tomatoes. Often puree from trimmings and cores is added to fill the spaces between the pieces and to cheapen the product, by utilizing otherwise waste material. The cans are often filled by machines which add the product

by volume rather than by weight. The standard tomatoes are just as nutritious and wholesome as the solid-pack and are cheaper. Therefore they have a legitimate place, if carefully prepared and not mixed with too much puree.

Addition of Water.—The addition of water to tomatoes is never necessary or desirable and constitutes an adulteration. Bitting[1] has studied the effect on the composition of the canned product of the addition of various amounts of water at the time of canning as set forth in Table 35.

TABLE 35.—EFFECT OF ADDITION OF WATER ON CUT-OUT WEIGHTS AND COMPOSITION OF CANNED TOMATOES
(*After Bitting*)

Water added, ounces per No. 3 can	Drained weight of tomatoes, ounces	Weight of liquid, ounces	Specific gravity of liquid
0	23.1	11.2	1.023
0	21.3	13.0	1.022
2	19.5	14.9	1.021
4	18.1	16.5	1.020
6	17.2	17.5	1.018
8	15.1	19.3	1.018
10	14.2	19.4	1.017
12	13.6	19.7	1.014
14	10.8	21.5	1.013
16	9.8	22.3	1.011

Tomatoes are sometimes packed whole in a single layer in flat shallow No. 3 or No. 10 cans for use in salads and are given a short sterilization in order to avoid softening.

Exhausting.—Tomatoes should be thoroughly exhausted at a moderate temperature because solid-packed tomatoes heat very slowly. The center of the can should reach at least 130°F., if possible 150°F., and the length of the exhaust should be adjusted to accomplish this end. Too short an exhaust may result in springers or flippers through overfilling or in the development of hydrogen swells and perforation.

Sterilization.—The agitating continuous cooker for tomatoes, operating at 212°F., has largely superseded the retort and the open cooker formerly used. Most canners of tomatoes are also canners of fruits and find it convenient and economical to utilize as far as possible the same equipment for both products.

In an open non-agitating cooker, tomatoes are sterilized for 30 to 55 minutes at 212°F. in No. 2½ and No. 3 cans. The length of time varies according to the consistency of the pack. Solid-pack tomatoes conduct heat more slowly than standard-pack goods and hence require a

longer processing. In the agitating continuous sterilizer the time has been reduced as low as 15 minutes.

Tomatoes should be cooled completely and quickly after sterilizing in order to avoid "stack burning," that is, browning of the color and loss in flavor.

Cut-out Weights.—The total net contents of a No. 2½ can should weigh at least 28 ounces, of a No. 3 can 33 ounces and a No. 10 can at least 103 ounces, although no minimum standards for net drained weights have been established by the Government. Tomatoes vary greatly in consistency and in the weight of the drained material on the cut-out test, according to variety, season, location and to the temperature and time of sterilization.

Grades.—Tentative definitions and standards for canned tomatoes and for canned tomato grades have been proposed by the joint committee on definitions and standards in the Bureau of Chemistry, U. S. Department of Agriculture, as follows:

> *Canned tomatoes* are the canned vegetables prepared from sound, ripe, fresh tomatoes (the fruits of *Lycopersicum esculentum* Mill.) of any red variety or varieties, by thorough washing and scalding and by proper peeling, coring, and trimming, with or without grading, with or without the addition of sugar and salt, and sterilized by heat. The liquor used for filling the space between the fruits is the pure juice derived from the tomatoes so prepared or from others of the same quality and preparation, and does not exceed in quantity that originally present in the prepared fruit contained in the can.
>
> *Canned Tomato Grades.—Fancy tomatoes* are canned whole select tomatoes of uniform red color, free from pieces of skin or core, and are with or without almost whole tomatoes, and with or without a few large pieces.
>
> *Extra standard tomatoes* are canned tomatoes practically free from under colored parts, from pieces of skin or core, and most of them whole or in large pieces.
>
> *Standard tomatoes* are canned tomatoes reasonably free from undercolored parts, and from pieces of skin or core.
>
> *Substandard tomatoes* conform to the definition for "canned tomatoes," but lack in some respects the qualifications of the higher grades.

The Pure Food and Drug Regulations require that canned tomatoes containing puree from trimmings (cores, etc.) shall be labeled to indicate this fact. Canned tomatoes without further designation cannot, according to Food Inspection Decision 144, contain added puree, or juice in excess of the amount normally present in tomatoes.

Sanitation.—Tomatoes are juicy, and machinery and floors are liable to become covered with juice, etc., in which molds, yeasts and bacteria rapidly develop. Workmen in an unclean factory become careless and the unsanitary condition of the plant becomes aggravated unless the superintendent insists upon frequent and thorough "clean-ups" during the day.

Buckets and pans should be washed each time they are used and floors should be washed at least twice daily. Machinery should be frequently washed which in some cases means partial dismantling of certain machines and this should be followed by hand scrubbing of working parts.

If tomatoes are to arrive at the plant in sound condition lug boxes must be frequently washed.

See Chapter XIX for further discussion of sanitation.

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CHAPTER XIV

THE SPOILING OF CANNED FOODS

All canned foods, after sterilization, are subject to deterioration during storage. In many cases the changes that occur do not render the food unfit for consumption; nevertheless the appearance of the container or of the product may become so unattractive that it becomes unsalable. Two general types of deterioration are recognized: first, spoiling by microorganisms, and, second, changes brought about by chemical or physical agencies. Microbiological spoiling of canned foods is the more important.

DEFINITIONS

Spoiled cans of food exhibit characteristic differences in appearance, taste and odor from normal cans. The most common designations in use for the different types of spoiled or abnormal cans of food are given below.

Swell.—A swelled can is one whose ends are tightly bulged from the formation of gas within the can by microorganisms and the ends of which remain convex and spring back to this position if pressed inward. Swelled cans of food are usually so badly decomposed as to be unfit for consumption. They may be poisonous because of the presence of *Bacillus botulinus* (*Clostridium botulinum*).

Hydrogen Swell.—A hydrogen swell is caused by the formation in the can of hydrogen gas as a result of corrosion of the tin plate. They are usually sterile and the contents often fit for food.

Springer.—A springer may be merely a mild swell, or a mild hydrogen swell, or may be caused by overfilling the can, or by insufficient exhausting. Swells always pass through the springer stage. The ends, or at least one end, of a springer can be pressed in with the hand and will remain convex for a time. Springers, if caused by overfilling, underexhausting or corrosion, can be used for food.

Flipper.—A flipper is a can under very mild positive pressure. It may be of normal appearance, but the end if struck sharply against the top of a table or other solid object, will become convex. It may represent the initial stage of a swell or hydrogen swell or, more frequently, be due to overfilling or underexhausting.

Flat Sour.—A flat sour is a can of food which has undergone spoilage by microorganisms without gas formation, and is normal in outward

appearance. The product usually possesses a sour taste and frequently a sour odor. Vegetables frequently undergo this type of decomposition, which is usually a non-poisonous change. Occasionally this condition is caused by bacterial spoiling before canning.

Leakers.—Cans may leak because of (1) faulty seaming of the factory end of the can, (2) faulty seaming of the cannery end of the can, (3) faulty lock seaming, (4) pinholing by corrosion from the inside of the can or rusting of the outside of the can and (5) bursting of the can by excessive gas pressure developed in the can by decomposition, by microorganisms or by formation of hydrogen gas through corrosion.

DISCOLORATION

While not as serious a cause of loss as spoiling by microorganisms, discoloration is nevertheless a serious problem for the canners of vegetables and apples.

Corn.—There frequently develops in canned corn a dark gray color throughout the product, or an inky-black, scale-like deposit on the interior of the can. The problem has been investigated by Bigelow[1] and his associates of the National Canners' Research Laboratory, and their conclusions are that the darkening of the entire contents of the can is due to the formation of copper sulphid and that the black deposit on the tin plate is iron sulphid.

Copper Sulphid.—It was found in their experiments that as little as one part of copper per million parts of corn was sufficient to produce appreciable darkening. The trouble is most likely to occur during the first part of the canning season or after the plant has been shut down for a few days, because of the formation of a thin film of copper oxide or copper salts on the surface of copper kettles or other copper or brass equipment with which the corn comes in contact at some stage in the canning process. The copper oxide, or salt dissolves and reacts with the hydrogen sulphid formed from the decomposition of the protein of the corn during sterilization.

Iron Sulphid.—The formation of the black scale or black deposit of iron sulphid is a much more serious problem than the darkening caused by copper salts. The sulphid is intensely black, is very finely divided and therefore a relatively large amount of corn may be colored by a very small amount of this compound. It is not injurious to health and only the appearance of the corn is affected.

Bigelow[9] states that there are two distinct steps in the formation of the deposit: first, a corrosion of the plate during processing, and later a combination of the dissolved iron with the hydrogen sulphid formed during sterilization. He also states that the deposit does not normally form in

direct contact with the corn because of the inhibiting effect of the acid of the corn, and that the principal formation of the black deposit occurs on the plate above the level of the corn.

Fitzgerald,[3] Bohart and Kohman have made an exhaustive study of the problem and have come to the following conclusions: (1) No variety of corn is free from discoloration. (2) There is no procedure known by which the canner may control his conditions or methods in order to prevent the formation of iron sulphid discoloration in canned corn. (3) Iron sulphid discoloration occurs with both bessemer and open-hearth steel. (4) The use of heavy tin coating does not prevent the discoloration. (5) Discoloration occurs less with acid flux cans than with rosin flux cans but empty acid flux cans, however, are liable to rust in storage. (6) Discoloration becomes more pronounced as the maturity of the corn increases. (7) Discoloration is less objectionable when the cans are stored on the side. (8) The black discoloration can be more readily dispersed by shaking when the consistency is not too heavy. (9) The smaller amount of discoloration noted in former years in solder top (hole and cap) cans was undoubtedly largely due to the fact that the cans were made with acid flux and that comparatively large quantities of acid flux were introduced into the can during the closing operation. (10) Changing the profile of the can to cause less strain on the steel or less disturbance of the coating does not prevent blackening. (11) Discoloration is no worse in cans made of black plate with no tin coating than in those carrying a heavy tin coating. (12) Tight seams are necessary to avoid air and rust discoloration which accelerate formation of the black sulphid. (13) No practicable method was found for preventing the formation of black by mixing any substance with the corn. Many different organic and inorganic substances were tested in this connection. (14) Zinc salts greatly reduce the formation of black, but when mixed with the corn, the amount necessary is so great as to be impracticable. When dissolved in water and allowed to dry on the surface of the can, much less is required. The salts may be replaced by zinc plating the lid of the can, which gives promise of yielding practical results, very much less zinc being required apparently in this form than in any other. (15) Discoloration due to bacterial action may follow insufficient cooling, but this blackening occurs throughout the contents of the can. (16) Corn should be filled into the can hot, at a temperature of at least 190°F. and the cans should also be filled as completely as possible. Both of these steps are taken to reduce the amount of air in the corn and in the head space. (17) All corn should be well shaken before shipment to disperse the black deposit, and heating before shaking is desirable to give a more liquid consistency. (18) All wholesalers should be warned that blackening may occur in storage in their warehouses and that cans should be placed on their sides instead of on end.

Zinc sulphid is white, a fact which explains why zinc salts prevent the formation of the black deposit.

Paper gaskets if not tightly rolled in double-seaming may "breathe," that is, admit air slowly. This condition results in increasing the amount of deposit. The oxygen thus admitted first causes rusting and the iron oxide thus formed is later converted to the sulphid. Fitzgerald[2] found that corn heated for 6 hours by intermittent sterilization (2 hours on each of 3 successive days) gave a product equal in flavor to freshly cooked corn and with no black deposit. Evidently the H_2S is formed at higher temperatures than 212°F. The corn in the above experiment, however, finally underwent bacterial decomposition because 212°F. did not sterilize.

In general it may be said that the darkening is favored by the presence of oxygen and by the use of overmature corn. Therefore, thorough precooking, complete filling and sealing of cans above 190°F., tight seaming of the cans and the use of young, tender corn are to be recommended.

Blackening of Peas.—Peas sometimes develop a flaky black deposit similar in appearance to, and probably identical in composition with, the iron sulphid deposit in cans of corn.

It has been found by Marre[3] that allowing the peas to undergo heating or sweating before canning increases the tendency for the formation of the black deposit. It is probable that the incipient decomposition which occurs under such conditions results in the formation of H_2S from the breaking down of protein. It is therefore to be recommended that peas be canned as promptly as possible after harvesting.

Thorough washing and blanching before canning, it is believed, also reduce the tendency for formation of the black deposit. Peas sometimes dissolve copper from unclean equipment with a subsequent development of a black deposit of copper sulphid.

Black Deposit in Canned Fruits.—Canneries in California during the 1921 season suffered some loss through the use of a grade of cane sugar known as "plantation granulated," in the manufacture of which sulphur dioxid is used. It is usually very light yellow or nearly white in color, is cheaper than refined sugar and if free from sulphur dioxid can be used satisfactorily for peaches, other dark fruits and berries. The experience of the 1921 season, however, proved that it sometimes contains sufficient sulphur dioxid to cause serious blackening of the tin plate and in some cases the production of a hydrogen sulphid odor. The sulphurous acid reacts upon the plate and is reduced to hydrogen sulphid, which in turn reacts with the dissolved metals to produce a black deposit of metallic sulphid.

Sulphur from new sorting belts has occasionally caused a black deposit in canned fruits by reduction in the can to H_2S and subsequent combination with iron to give iron sulphid.

Pink Pears and Peaches.—If canned peaches and pears are not thoroughly cooled after sterilization they will frequently become pink in color. It has also been claimed, but not proved experimentally, that overheating of the fresh fruit before canning, during shipment or storage, will result in the formation of a pink color after canning and that pears grown in very hot localities frequently develop a pink color after canning.

Pumpkin.—Canned pumpkin frequently "detins" the container and causes the formation of a heavy black deposit on the exposed steel surface. According to Huenick[7] the corrosion is due to the amino compounds of the pumpkin; however, the use of heavily lacquered cans prevents this trouble.

Apples.—Apples will cause vigorous corrosion of tin plate if not thoroughly exhausted or otherwise treated before canning to expel air from the can and from the fruit tissues. The dissolved iron may react with the tannin of the fruit to produce a black color.

Browning of apples before canning sometimes occurs. Placing the peeled and cut fruit in dilute brine and thorough blanching before canning will eliminate this type of discoloration.

Sweet Potatoes.—According to Kohman[4] the darkening of sweet potatoes is caused by a combination of the tannin of the potatoes with ferric iron compounds dissolved from the plate. Slack filling of the cans and the entrance of air through leaks permit corrosion and subsequent darkening of the potatoes to take place. In some respects the problem resembles that of the formation of the black deposit in corn.

CORROSION AND PERFORATION OF TIN PLATE

A large quantity of canned food is lost annually because of corrosion and perforation of the tin plate, the greatest loss occurring with acid fruits, such as apples, plums and berries, although perforation may also occur with less acid products, such as pumpkin.

Relation of Oxygen to Corrosion.—H. A. Baker,[5] one of the first to point out the relation between corrosion of tin cans and oxygen supply, found that the oxygen rapidly decreased in cans after sealing and sterilizing. His investigations indicated that the oxygen combines with the metal of the container, with the food or with the nascent hydrogen formed by action of acid on the metal. He recommended that oxygen be excluded from the can as completely as possible by thorough exhausting and proper filling.

During the past few years a cooperative series of investigations has been made by representatives of the National Canners' Association, the can manufacturers and the steel plate manufacturers. Investigations have also been made by various laboratories in America and in Europe. In practically all cases the investigators emphasize the fact that corrosion

of tin by fruit acids is dependent to a very marked degree upon the presence of oxygen. Undoubtedly corrosion will take place in the absence of oxygen, but the rate of the reaction is enormously increased by its presence.

In the presence of oxygen the can acts as a primary cell of the oxidation type. That is, the reactions which occur in the can may be explained upon the basis of an electrolysis in which oxides of tin and iron are formed and hydrogen is liberated.

Bigelow[6] has recently emphasized the importance of removing as much of the air as possible from the can before sealing, because of the action of oxygen in accelerating corrosion.

Effect of Fill of Cans.—Every means available should be employed to reduce the amount of air in the can since oxygen accelerates the corrosion of tin plate. Filling the can as completely as consistent with effective sealing reduces the head space and the volume of air contained therein; therefore slack filling should be avoided.

Preheating.—Canned apples are particularly active on the plate. It has been demonstrated by Huenick and others that the pulp of this fruit contains a relatively large amount of air, which is not usually removed by exhausting in the usual manner. This fact explains the customary practice of preheating the prepared fruit before placing in the can. Several other methods of pretreatment are in use (see Chapter XI).

Recently, the removal of air from apples by heating in dilute brine at 120°F. has been studied by Huenick, who finds that the following amounts of air are obtained from the fruit heated at 120°F. for the respective lengths of time indicated. The volumes of air are expressed in percentages of the total volume of the fruit. Heating for 20, 60, 120, 180, and 240 minutes yielded 8, 8+, 9, 10 and 12 per cent of air respectively. He recommends 20 minutes' heating at 120°F. as sufficient for practical purposes, as higher temperatures cause browning, but the fruit may be held at this temperature overnight without injury. Dilute brine (3 per cent salt) is preferable to water, because slight browning of the edges of the pieces is liable to occur in water. The air may also be removed by subjecting the fruit to a high vacuum in a liquid such as water or dilute brine.

Exhausting.—Thorough exhausting of canned fruits serves the same purpose as preheating, namely, the expulsion of air from the fruit and liquid. A long exhaust at a moderate temperature is much more effective in expelling air than a short exhaust at a high temperature.

Usual Method.—The usual style of exhaust box is heated by live steam, which gives a relatively high temperature, usually above 200°F. If open cans of fruit are subjected to a long period of exposure to the direct steam the fruit in the top of the can becomes softened. If softening is avoided by a short exhaust, 2 to 4 minutes, air is not

effectively expelled, even though the liquid in the center of the can may reach 165 to 175°F., because this short period of heating does not even heat the fruit thoroughly.

An improvement over the usual method of exhausting consists in placing lids on the filled cans, in clinching the lids to the cans by passing them through the first rolls of a double-seamer and exhausting the cans in hot water. This permits escape of air from the can but prevents direct contact of steam with the fruit. This can only be done safely with lids equipped with rubber gaskets because paper gaskets are liable to become wet and crumpled during the final seaming operation and thus imperfectly sealed.

Exhausting in Water.—Exhausting in water at 185 to 190°F. permits of more careful control and does not result in softening of the fruit in the top of the can. Bigelow[5] recommends a 6 to 8-minute exhaust in a hot water exhaust box about 20 feet long and wide enough to permit 10 No. 2 or 6 No. 10 cans to be carried abreast through the exhaust box by means of a suitable belt. The water level is at about 1½ inches below the tops of the cans and is maintained at 180 to 190°F.

Vacuum in Cans.—Bigelow recommends that exhausting should be so conducted that the vacuum in the cans after sterilizing and cooling to room temperature will be for No. 10 cans about 8 inches, for No. 3 cans 12 to 15 inches and for No. 2 cans 20 inches. Some canners desire a vacuum of only 5 inches in a No. 10 can. If the vacuum is much in excess of the above amounts the cans may show excessive paneling, and if the vacuum is much less it may indicate the presence of an excessive amount of air.

Vacuum Sealing.—It is possible to remove air from fruit and liquids by treatment under a high vacuum. It is also possible to seal cans in vacuo. Therefore it is probable that canned fruits and vegetables could be thoroughly exhausted under a vacuum and vacuum-sealed without use of the present method of exhausting by heat. The method is already in use for canned dried prunes, coffee and salmon.

Sealing in Inert Gases.—Recently a new process of checking corrosion has been developed in New York by Rector and Tenney and described in *The Canning Age.* The filled cans are first subjected to a vacuum to withdraw air, a neutral gas (CO_2) is admitted, and this gas is then removed under a vacuum and fresh gas again admitted. This process is repeated several times and the can is finally sealed with the neutral gas filling the head space of the can. The process was developed primarily for dry or semi-dry products, but it is stated that it can also be applied successfully to foods packed in syrup or brine. The pressure inside the can is equal to atmospheric pressure and for this reason the tendency to form leaks is reduced. The neutral gas used does not favor corrosion..

Importance of Effective Sealing.—Not only must the air be effectively removed from the can and contents before sealing but its entrance must be prevented after sterilization by perfect sealing of the cans.

Cans equipped with paper gaskets may be sealed tightly enough to exclude microorganisms, but still admit air slowly. The gasket in such cases acts as an air filter and such cans are commonly known as "breathers." Rapid corrosion usually follows and the blackening of corn in some cases is attributed to this cause. The remedy lies in rolling the seams so tightly in the double-seamer that air cannot enter. Bigelow[6] states that the can factories' end of the can is usually airtight because the cans are sealed in a dry plant under carefully controlled conditions, while the canners' end of the can is the one most likely to be loosely sealed, and recommends storing the cans with the canners' end downward so that the paper gasket is wet by the syrup or brine and the seal made more effective.

The rubber composition gasket is less apt to permit air to enter, but if imperfectly sealed, admits not only air but microorganisms as well. Imperfect sealing therefore becomes evident at once by the appearance of swells and bacterial spoiling.

Effect of Temperature of Storage.—Like all other chemical reactions the rate of corrosion of tin plate is more rapid at high than at low temperatures and the storage of canned fruit in hot warehouses is therefore to be avoided.

Cooling.—If the cans are packed into boxes while still hot or stacked closely together in the warehouse before cooling, they remain warm for several days, with consequent excessive corrosion. Prompt cooling is therefore advised.

Effect of Character of Tin Plate.—Ordinary tin plate is known as coke plate and carries about 1½ pounds of tin per base box. A grade of tin plate known as Charcoal-A, or Char-A, used rather extensively for the preparation of cans used for fruit canning, carries about 2½ pounds of tin per base box, and for very acid products it is to be preferred to the coke plate.

It has been recognized that the tin coating is not perfect and that rather numerous small areas exist in which the steel plate is exposed; usually these exposed areas are very small. Bigelow[6] states that there are hundreds of these exposed areas on the surface of a single can and that increasing the weight of the tin coating does not eliminate these exposed areas.

The coating of the tin plate with lacquer, while it reduces the total amount of tin that goes into solution, greatly increases the tendency for the formation of pinholes. Kohman attributes this condition to slow disappearance of the oxygen in the lacquered can with consequent prolonged contact of the acid juice and tin with oxygen. In the plain tin can

the oxygen rapidly combines with the tin plate over a wide surface and action is therefore not excessive at any one point.

Testing Tin Plate.—It is sometimes desirable to test tin plate in order to determine the completeness of the coating of the steel plate with tin. This can be done by filling several cans with the following solution: water 1 gallon, concentrated hydrochloric acid 1 cubic centimeter, potassium ferricyanide 5 grams, and enough gelatin to cause jelling of the solution on cooling. A blue color will develop where the steel plate is not coated with tin.

Tin in Canned Foods.—All canned foods contain some tin in solution or in combination with the product. At one time a federal regulation placing the maximum tin content of canned foods at 300 milligrams of tin per kilogram was enforced but at the present time food inspection officials do not attempt to apply the rule rigidly.

It has been proved by Bigelow[9] and others that most of the tin in such foods is not to be found in the liquor but in the drained solids. The following analyses taken from Bigelow's published results will indicate the relation of the tin content of the liquor and the solids.

TABLE 36.—TIN CONTENT OF SOLIDS AND LIQUOR FOR SEVERAL IMPORTANT CANNED FOODS

(Tin reported in milligrams per kilogram, or parts per million)
(*After Bigelow*)

Product	Tin in liquor	Tin in drained solids	Total tin
Cherries	52	163	107
Cranberries	33	254	170
Raspberries	39	294	194
Peaches	86	251	193
Pears	99	151	130
Plums	43	180	125
Shrimp	67	381	224
Spinach	35	131	86
Asparagus (1 year)	252	489	433
String beans (1 year)	97	442	299

Asparagus after 8 months storage contained 280 milligrams of tin per kilo and after 31 months, 470 milligrams; lima beans after 9 months storage contained 80 milligrams of tin and after 33 months, 173 milligrams; wax beans contained after 3 months, 93 milligrams and after 30 months, 347 milligrams of tin per kilogram.

Storing Foods in Open Cans.—Many housewives and others firmly believe that food stored in an open tin can overnight contains dangerous

amounts of tin. Bigelow reports in Bulletin 2 of the National Canners' Research Laboratory the results of a number of experiments upon the rate of solution of tin by various products in open cans. Some of the data appear in the following table:

TABLE 37.—RATE OF SOLUTION OF TIN DURING STORAGE OF FOOD IN OPEN CANS

(In milligrams per kilogram)
(*After Bigelow*)

Product	Tin on opening	Tin after 1 day's storage	Tin after 2 days' storage	Tin after 3 days' storage
Apples	59	81	91.5	129
Corn	12	15	14.0	11
Sauerkraut	44	51	74.0	113
String beans	144	138	143.0	160
Pumpkin	314	312	360.0	407
Tomatoes	68	69	93.0	143
Pineapple	75	97	102.0	158

The rather rapid solution of tin between the second and third days in some cases was due to fermentation or decomposition in other ways by microorganisms. In general it may be stated from these data that the amount of tin dissolved on standing in the open can is small and that the current fear of food that has been allowed to stand in the can overnight is unfounded.

FLAT SOURING OF CANNED FOODS

The ends of a can which has undergone flat souring appear normal and the can is not noticeably under gas pressure but is sour in taste.

Corn.—The first investigators to publish data on the flat souring of canned corn were Prescott and Underwood,[11] who studied the souring of corn in Maine canneries. The authors spent an entire packing season in a cannery in order to study packing methods and conditions, and found that cans which did not give visible evidence of spoiling were sterile and that spoiled cans contained living organisms or gave unmistakable evidence of bacterial action. They isolated pure cultures of eleven bacilli and one micrococcus and of these organisms eleven formed spores, one produced gas and all except one produced acid. Prescott and Underwood stated that flat souring of corn is more common than swelling and that the latter condition develops only under exceptional conditions. They were able to reproduce the flat souring by inoculation of sterilized cans of corn with pure cultures of most of the organisms studied. Numer-

ous investigations have been made in recent years upon the flat souring of corn. (See also section on "Thermophiles.")

Other Vegetables.—Asparagus canners in California have experienced some loss through the development of flat sours, in some cases caused by thermophiles.

Spinach is packed so tightly into the cans that heat penetration is greatly retarded and sterilization is frequently not complete; for this reason flat souring in addition to gaseous spoilage occurs frequently.

Pumpkin and sweet potatoes occasionally undergo flat souring. Because of the poor heat conductivity of these two products, they are difficult to cool and for this reason are particularly favorable for the growth of thermophiles. Nearly all canned vegetables are subject to flat souring, if conditions are favorable.

Thermophiles.—Bigelow[15] and his co-workers have demonstrated that much of the flat souring of canned vegetables, particularly corn and pumpkin, is due to the growth of thermophilic bacteria, which develop at relatively high temperatures only, usually above 100°F. When canned vegetables are not well cooled and are allowed to stand in large stacks with the cans piled so closely together that rapid radiation of heat is prevented, the contents of the cans remain at the incubating temperature for thermophilic bacteria long enough for spoiling to occur. This condition has developed frequently in the past, but now canners realize more generally the danger of such practice and loss from this cause is decreasing.

Bigelow[15] and Esty have made extensive thermal death point investigations upon a number of resistant thermophilic bacteria in media of different hydrogen ion concentrations. One thermophile, No. 26, withstood a temperature of 100°C. (212°F.) for 1,260 minutes (21 hours) and 115°C. (239°F.) for 80 minutes in corn juice. A heating of 3½ hours at 100°C. was required to destroy the spores of the least resistant of 14 other organisms reported upon, and 20 hours at 100°C. for those of the most resistant strain.

These investigators found that the hydrogen ion concentration of the medium exerts a marked influence on the thermal death point of thermophiles. Table 38 contains data which illustrate this effect. Of the vegetables given in the table, corn possesses the lowest acidity (highest P_H value) and pumpkin the highest hydrogen concentration (lowest P_H value). The data show that the spores in most cases in pumpkin juice were killed in about one-sixth the time required for those in corn juice. This fact illustrates in a very striking manner the fallacy of specifying processing times for a given product based upon data obtained for another product of different composition.

A similar relation probably holds for most other microorganisms causing the spoiling of canned foods.

TABLE 38.—EFFECT OF HYDROGEN ION CONCENTRATION ON THE THERMAL DEATH POINT OF THERMOPHILIC ORGANISMS

(Temperature 115°C., 239°F.)

(*After Bigelow and Esty*)

Culture	Number of spores per cubic centimeter	Minutes required to destroy spores heated in									
		Corn juice PH 6.1		Pea juice PH 6.3		Sweet potato juice PH 5.0		String bean juice PH 5.0		Pumpkin juice PH 4.5	
		+	−	+	−	+	−	+	−	+	−
1503	150,000	60	63	45	48	28	30	20	25	10	10.5
4109	40,000	58	60	40	45	25	28	15	18	10	11.0
1390	60,000	55	58	35	40	25	28	6	7	6	7.0
1549	50,000	35	40	25	30	15	18	10	12	5	6.0
1492	10,000	30	35	12	15	9	10	6	7	4	5.0

Summary of Flat Souring.—By way of summary of the flat souring of canned foods it may be said that: (1) Flat souring occurs more frequently in canned vegetables than in other types of canned foods. (2) It may be caused by: (*a*) non-resistant bacteria which enter the cans through leaks; (*b*) spore-bearing organisms which survive processing and which develop at ordinary storage temperatures; (*c*) spore-bearing thermophiles which survive processing but develop only at temperatures above 100°F. (3) Flat sours can be eliminated by perfect sealing of the cans and complete sterilization. (4) Efficient and rapid cooling will reduce loss from spoiling by thermophiles of imperfectly sterilized products.

NON-POISONOUS GASEOUS SPOILING

Gaseous decomposition occurs with all canned goods under favorable conditions. Gaseous spoilage may be classified as non-poisonous and poisonous.

Fruits.—Examination of swelled cans of fruit usually reveals the presence of yeast cells and evidence of alcoholic fermentation. Yeasts are very rapid producers of carbon dioxid, which accounts for the frequent bursting of spoiled cans of fruit. In a very few instances only are bacteria found to be the cause of spoiling of canned fruits, although occasionally found in pears and less frequently in peaches, both being fruits of low acidity.

Spoiling of canned fruit by yeast usually signifies leaky cans or gross carelessness in sterilization. An exception to this statement is the spoiling of solid-pack pie fruit, in which heat penetration is so slow that the centers of No. 10 cans may not reach a temperature fatal to yeasts, if the sterilizing process used for syrup-packed fruits is applied.

Vegetables.—The first important bacteriological investigation of swelled canned vegetables was conducted by H. L. Russell[16] at the Univer-

sity of Wisconsin in 1895, at a time when the canners of Wisconsin were losing large quantities of canned peas. They knew very little about bacteria and placed the blame for the spoiling upon various factors later proved to have little or no relation to the problem. From swelled cans of peas Russell isolated two species of bacteria, of which one produced typical swells when inoculated into sterile cans of peas. He recommended the increase of the processing temperature from 232 to 242°F. and the time from 26 to 28 minutes. Previous to the adoption of this recommendation the number of swells had been about 5 per cent of the total pack; after its adoption, this type of spoiling was reduced to a negligible amount.

Prescott and Underwood at the Massachusetts Institute of Technology in 1896 and 1897 made important contributions to the knowledge of the swelling of canned corn. Their investigations, while more extensive than those of Russell, yielded similar results. Other canned vegetables, notably spinach, undergo gaseous spoiling, if not well sterilized.

Because of the low oxygen content of canned foods, spoiling is usually caused by anaerobes or facultative anaerobes. Of the spore-bearing gas formers, *Bacillus sporogenes* and *Bacillus welchii* which produce a very disagreeable putrid odor, are among these most commonly found in swelled cans of vegetables. Organisms of the *B. coli* group frequently cause gas formation in leaky cans, but owing to the fact that they do not form spores, they very rarely survive processing.

The heat-resistant organisms occurring on peas were studied extensively at the Michigan Experiment Station by Ruth Normington,[17] who described seven strains of spore-bearing, heat-resistant, gas-producing bacteria. One of these (organism *C*) closely resembled *B. botulinus*, another (organism *B*) conformed to the description of *B. subtilis* and a third (organism *E*) resembled *B. ramosus*. She found that pure cultures of *B. subtilis*, *B. ramosus*, *B. ruber*, *B. prodigiosus*, *B. viscosus* and some of the organisms isolated by her from peas produced gas in peas but not in other media. All of Miss Normington's spore bearers withstood 110°C. (230°F.) for 10 minutes and most of them survived 120°C. (248°F.) for 10 minutes. She advises the use of pressure sterilization in preference to processing in boiling water.

BOTULISM AND BACILLUS BOTULINUS (*Clostridium botulinum*)

The term "botulism" is used to designate a type of poisoning caused by the toxin of *Bacillus botulinus* (*Clostridium botulinum*). According to Dickson[18] the word "botulism" was coined early in the nineteenth century by physicians in southern Germany to apply to a peculiar type of food poisoning resulting from the ingestion of spoiled sausages. Synonomous terms are "allantiasis" and "Wurstvergiftung" (sausage poisoning). So-called "ptomain poisoning" is often botulism.

Bacillus botulinus (*Clostridium botulinum*) has become of very grave concern to the canning industry because of the outbreaks of botulism from both commercially canned and home-canned products in recent years.

History.—The first recorded case of botulism occurred in 1735 in Germany, and following this date references in the medical literature of Germany to botulism are frequent. Dickson summarizes the German reports as follows:

1793–1820, 76 cases, 37 fatal
1820–1822, 98 cases, 34 fatal
1822–1886, 238 cases, 94 fatal
1866–1913 about 800 cases, about 200 fatal
Total 1793–1913 about 1,212 cases, about 365 fatal
Fatality, about 30.1 per cent.

Nearly all of these outbreaks were from meat products.

The most interesting of the German outbreaks occurred in Darmstadt in 1904 and was reported by Fischer.[19] It was caused by eating salad prepared from home-canned green beans and was, until that date, the only case reported in European literature in which poisoning was caused by other than animal products.

K. F. Meyer[21] has summarized the history of botulism in the state of California from 1900–1920 as follows: 39 outbreaks among human beings with a probable total of 139 cases, of which 94 were fatal, or equal to a mortality of 72.3 per cent; 42 outbreaks among fowls from eating canned foods and 18 outbreaks of forage poisoning among animals, a total of approximately 161 outbreaks.

It has frequently happened that housewives or others have opened a jar or can of food and have, after noting a peculiar odor, thrown the material to the chickens with fatal results to the fowls. In one case 643 chickens were killed from eating garbage and other kitchen refuse into which had been thrown four jars of spoiled home-canned beans.

Other cases could be enumerated, but these will suffice to indicate that the organism is by no means confined to meat products and, in fact, occurs, in the United States at least, frequently in canned vegetables and fruits, particularly the home-canned articles. This latter situation is to be expected because of the frequent lack of knowledge of the principles of sterilization on the part of home canners.

Distribution of the Spores in Nature.—K. F. Meyer in a paper read at the University of California has proved that the spores of *Bacillus botulinus* are widely distributed in nature and that they occur very frequently in soil samples representing practically every state in the Union, although a larger percentage of the samples from Pacific Coast States than from Eastern States were positive. He has demonstrated that samples of virgin soil contain the organism more frequently than samples of

cultivated soil from the same regions. He has recovered the organism from practically 100 per cent of the samples of virgin soil from the Yosemite Valley and from a number of similar samples from Yellowstone Park. It is therefore evident that *B. botulinus* is not necessarily a filth organism.

Burke[25] recovered the organism from a spoiled jar of home-canned string beans, from the soil in the garden in which the beans were grown and from the vines themselves. Meyer reports a similar chain of evidence from a case in northern California and has recovered the organism frequently from fresh fruits and vegetables.

It is probable that the failure of early investigators to recover the organism from the soil and from fresh foods was due to faulty technique. By incubating large samples of soil anaerobically in a suitable nutrient medium it has become possible to produce enrichment cultures from which the organism may be recovered or its toxin demonstrated, if the spores are present.

Relation of Botulism to Forage Poisoning.—Graham and his associates have repeatedly demonstrated that one type of so-called forage poisoning in animals is caused by *B. botulinus* toxin formed in the forage. Ensilage and musty hay or straw have been frequent causes of this type of poisoning. It is probable also that a disease known as "limber neck" in chickens may be caused by ingestion of botulinus toxin in the food.

Cultural Characteristics and Morphology.—Van Ermengem,[22] a Belgian scientist, was the first to prove *B. botulinus* to be the primary cause of botulism in man. At Ellezelles, in 1894 he isolated the organism from ham preserved in brine, which had caused the illness of 23 persons and the death of 3. He found the organism to be a large gram-positive, sporebearing, anaerobic bacillus, with large, oval spores, usually occurring at the ends of the cells, giving them a club-shaped appearance (see Fig. 46). He gave it the name of *Bacillus botulinus.* He found that infusions of the macerated ham and bouillon cultures of the organism produced the typical symptoms of botulism in guinea pigs, rabbits, cats, pigeons and monkeys, and proved that the bacillus itself is a saprophyte and that the poisoning is due to a toxin which is formed when the organism is grown under anaerobic conditions.

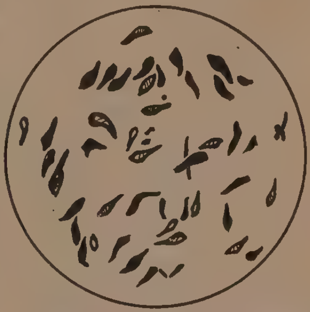

Fig. 46.—Bacillus botulinus (*Clostridium botulinum*) with spores. (*After Dickson*).

Other investigators have confirmed Ermengem's findings and added a great deal to our knowledge of this interesting bacillus.

Odor.—In most media it produces a very characteristic penetrating butyric odor, similar to that of rancid butter or Rocquefort cheese. This is most pronounced in meats and peas and is least noticeable in

string beans and fruits. Cases are on record, however, where the odor of the food causing botulism was not objectionable.

Although an anaerobe, *B. botulinus* can be grown in cultures exposed to the air in symbiosis with aerobic organisms.

Effect of Sugar and Salt.—Dickson obtained growth and toxin formation in 65 per cent cane sugar solution. Wyant[23] and Normington report growth of the different strains in 10 per cent brine.

Optimum Reaction.—The bacteria grow more readily in media containing glucose than in glucose-free media. Although it will develop in slightly acid media, the organism prefers a medium of neutral or faintly alkaline reaction, and a small amount of sodium chloride (.5 per cent) favors its growth. Gas is produced abundantly in glucose media and in glucose agar shake cultures the organism causes breaking of the agar from gas formation.

Size.—The bacilli are large, 4 to 6 by .9 to 1.2 microns, have slightly rounded ends and may arrange themselves in pairs, end to end. They are slightly motile and possess from 4 to 8 flagellae arranged around the periphery.

Beef heart media and brain media are excellent for growth of the organism.

Types of B. Botulinus.—Burke[25] at Stanford University found that there are at least two distinct types of *B. botulinus* which form different types of toxin. She has designated these as type *A* and type *B*, and finds that the antitoxin of type *A* will neutralize the type *A* toxin but not type *B* toxin, and vice versa. Type *A* is that usually found on the Pacific Slope and type *B* in the eastern United States. A number of different strains exist in each group. In general, type *A* produces a more virulent toxin than type *B* and is usually more resistant to heat, but in other respects than those noted above the two types are similar.

The Toxin.—Liquids in which *B. botulinus* has been grown can be filtered to remove all organisms and the filtrate will be toxic to animals when injected or when fed. The toxin, unlike most other bacterial toxins, is not destroyed in the digestive tract but is absorbed by the blood stream.

An antitoxin can be prepared by injecting animals with small doses of the toxin and will protect against the toxin if administered with it, but apparently it is of no avail if given after botulism symptoms have appeared.

Resistance of the Spore to Heat.—The characteristic of most importance to the canner is that of heat resistance. Van Ermengem[22] in 1897 and several later investigators determined the death temperature of *B. botulinus* spores to be 80°C. (176°F.) and textbooks have given this as the death temperature of the spores.

(*a*) *Dickson's Work.*—Dickson[24] in 1917 sounded a warning against the belief that *B. botulinus* is easily killed by heat and called attention particularly to the danger of the so-called "cold pack" method of home canning of vegetables. He inoculated jars of peas, beans and corn prepared according to the usual "cold pack" recommendations. The peas and beans were heated in boiling water for 120 minutes and corn 180 minutes in accordance with the "cold pack" method. Within 3 weeks all of the jars had undergone a gaseous fermentation, a number were leaking and the contents of the jars caused typical botulism symptoms and death when fed to guinea pigs and chickens.

(*b*) *Retarded Germination.*—A case of botulism in chickens developed in California in 1918 from feeding spoiled home-canned string beans processed in jars by the fractional sterilization method of heating for 1 hour in boiling water on each of 3 successive days. The ineffectiveness of the fractional sterilization is attributed by Burke[25] to the fact that heating the spores to 100°C. (212°F.) greatly retards their germination. In one case the spores germinated only after 20 days' incubation following heating to 100°C. Burke[25] investigated the heat resistance of ten strains of *B. botulinus* and found considerable variation in their resistance. One strain survived 4 hours' boiling, and one 10 pounds pressure (239°F.) for 20 minutes and 15 pounds pressure (250°F.) for 10 minutes. Dickson has found even more resistant strains.

From the published data it would appear to be desirable to employ for products of low acidity such processing times and temperatures that the center of the container is held at 240°F. for at least 30 minutes or processed for equivalent times at other temperatures.

Effect of Acidity.—In 1917 the writer inoculated peas, string beans, corn and fish in quart jars with spores of five strains of *B. botulinus* from brain medium. To one set of jars of each product was added 3 per cent brine containing 5 ounces of lemon juice per gallon, and to similar jars of each lot was added 3 per cent brine containg no lemon juice, all jars being processed in boiling water for 60 minutes. The acidified samples kept perfectly, and after 6 months' incubation showed no evidence of decomposition, and were not toxic to guinea pigs when administered subcutaneously. The peas, fish and corn samples spoiled which were not acidified, and developed the characteristic butyric odor and gas formation typical of spoilage by *B. botulinus.* The liquids from the corn and peas were injected subcutaneously into guinea pigs and caused death in 24 hours. The liquids in the jars contained a large gram-positive bacillus with oval spores, *i.e.*, the typical club-shaped cells of spore-bearing *B. botulinus* bacilli.

Dickson, Weiss, Wyant and others have confirmed the effect of citric acid and acetic acid upon the death temperatures of the spores of *B. botulinus.* The sensitiveness of the organism to these organic acids

probably explains why acid fruits are so readily sterilized and so rarely cause botulism.

LIVING ORGANISMS IN SOUND CANNED FOODS

It is often assumed that canned foods which do not undergo visible spoiling are sterile, but investigations have proved that this assumption is not correct in many cases.

Meats.—Weinzirl[28] states that in 1900 Vaillard in France examined bacteriologically a large number of samples of canned meats, many of which were edible and to outward appearance sterile, and found living bacteria in 70 to 80 per cent of them.

Sadler[26] found that normal cans of fish frequently contain living organisms. Hunter and Thom[27] found 224 out of 530 cans of commercially packed salmon to contain living spores of a resistant bacillus. There was no evidence of spoiling in any of these samples.

Weinzirl[28] at Harvard recently examined a large number of samples of canned meats, including sardines, and found that 19.5 per cent of 273 apparently sound commercial samples contained living organisms. Most of the organisms were spore-bearing aerobes. Canned oysters, clams, salmon and soups were found sterile in most cases.

Milk.— Sweetened condensed milk was found by Weinzirl[82] to contain *B. mesentericus* and *B. subtilis*. This product is not sterilized at a high temperature. Evaporated, unsweetened milk was sterile in most cases, because it is given a severe sterilization under pressure.

Fruits.—Most fruits are processed at 100°C. (212°F.) for a short period only. Therefore, it might be expected that spore bearers would survive and be found in commercially canned fruits.

In the examination of 104 cans of normal appearance, Weinzirl[28] found living mold spores in 4 cans and spore-bearing bacteria in 31 cans. *B. subtilis* occurred 14 times, *B. mesentericus* 10 times, *B. cereus* 8 times, *B. vulgatus* 3 times and thermophiles 9 times. Yeasts were not found. The fruit in all cases was normal in appearance and showed no evidence of bacterial growth.

Beresford at the University of California found viable spore-bearing bacteria in olives processed at 212 to 230°F. but none in olives sterilized at 240 to 250°F. for 20 to 30 minutes.

Vegetables.—Weinzirl reports results from the examination of commercially canned vegetables very similar to those given above for fruits. No yeasts were encountered in 370 samples of commercially canned vegetables of normal appearance. Molds occurred in 2 per cent of the cans and spore-bearing bacteria in 20.5 per cent. Much the same types of bacteria were found as listed above for fruits.

Incubation at 37°C. did not cause these organisms to develop in the unopened cans, probably because of lack of oxygen. The bacteria

were found to develop readily in the vegetables under aerobic conditions and apparently the absence of oxygen is the principal limiting factor, although Bigelow, Esty and others have shown conclusively that canned vegetables containing living thermophiles will keep perfectly unless stored at a temperature above 100°F.

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CHAPTER XV

UNFERMENTED FRUIT BEVERAGES

It was estimated by the U. S. Department of Agriculture in 1919 that about 3,000,000,000 bottles of soft drinks of various kinds are consumed annually in the United States, a more recent estimate places the total at 5,000,000,000 bottles. According to the *Western Confectioner* of July, 1921, $1,150,000,000 is spent annually in the United States for non-alcoholic beverages, including those served in soda fountains. The beverage industry, therefore, is of considerable economical importance.

It is to be regretted that the major proportion of the unfermented beverages represents synthetic drinks, artificially colored and flavored. There is undoubtedly an opportunity for a greatly increased production of pure fruit beverages for sale at popular prices and it has been demonstrated conclusively that pure fruit juice beverages can be produced profitably in competition with the synthetic products.

Types of Fruit Beverages.—Fruit juices and modified fruit juices are offered for sale in several forms, of which the following are probably the most inportant:

Bottled Still Juices.—Grape juice, sweet cider and loganberry juice are marketed in large quantities in non-carbonated form in bottles varying in size from 4 ounces to 1 gallon.

Canned Juices.—Canned cider, now produced upon an extensive scale in the apple districts of the Pacific Northwest, is sold at a low price and is increasing in popularity.

Carbonated Fruit Juices.—Much of the bottled apple juice is carbonated under a moderate pressure of carbon dioxide and some grape juice and loganberry juice is also marketed in this form.

Recently interest has developed in the diluting, bottling and carbonating of fruit syrups to replace carbonated synthetic beverages.

Modified Fruit Beverages.—Very large quantities of so-called "orange juice" beverages are now marketed annually at soda fountains and in bottled form. In some cases the drink as consumed by the purchaser contains less than 3 per cent of orange juice but in other cases an attempt is made to produce an orange drink consisting of orange juice, lemon juice and sugar only.

GENERAL METHODS AND EQUIPMENT

Fruit juices are most attractive when first expressed from the fresh fruit and any treatment applied to preserve or clarify them results in more or less injury to quality. Preservation and clarification must be accomplished with as little injury as possible to the fresh flavor and other desirable qualities of the product.

Choice of Fruit.—Fruit that is to be used for the preparation of juice should be of marked and agreeable flavor and aroma, must have "character," should not be flat or insipid in flavor and should be of tart flavor, that is, moderately rich in acid. In addition the juice should retain its character satisfactorily during processing and during storage after bottling.

Harvesting and Transportation of the Fruit.—Fruit juices must be prepared from sound fruit only and even slight fermentation or mold growth which would not seriously injure some fruits for other purposes, will spoil the flavor of the juice for beverage purposes. This fact makes it necessary also to use only clean boxes, free from mold, for picking and transporting the fruit to the factory.

The fruit should be picked at the proper stage of maturity for the preparation of juice, which will vary with the variety. Thus loganberries should be picked when they have become "dead" ripe, that is, soft ripe, for they are then at their optimum color and flavor. Vinifera grapes, with the exception of the Muscat variety, should be picked when slightly under-ripe, in order that the juice may not be too low in acidity and too rich in sugar. For the same reason apples should not be allowed to become over-ripe and mealy in texture before crushing.

Importance of Sorting and Washing.—Sorting is usually desirable and frequently necessary before the fruit is crushed, and can be accomplished in the same manner as described elsewhere for tomatoes.

Most fruits accumulate some dust in the field or during transportation and for this reason should be rinsed thoroughly by sprays of water before crushing. Fruit that has become contaminated by moldy fruit, as is sometimes the case with apples stored in bins, requires vigorous washing. Oranges in some sections develop a sooty mold deposit on the surface, which can only be removed by scrubbing and washing.

Berries and other soft fruits can be washed satisfactorily as they pass beneath water sprays on a woven metal conveyor.

Crushing.—Most fruits must be crushed to facilitate extraction of the juice by pressing.

Choice of Metal.—The crusher should be of such material that it does not react with the juice. Iron or steel rolls or knives are liable to cause darkening of some juices by the solution of a small amount of iron, which reacts with the tannin and coloring matter of the juice to produce a black or dark brown color. Grapes and apples can be crushed

safely with iron rolls or grated with steel knives, but bronze, aluminum, silver or nickel plated metal or other insoluble metal should be used in crushing berries and citrus fruits.

Apple Grater.—The most satisfactory crusher for general use is the apple grater, which can be used for the crushing of most fruits. It consists of a steel cylinder about 6 to 8 inches in diameter, on the surface

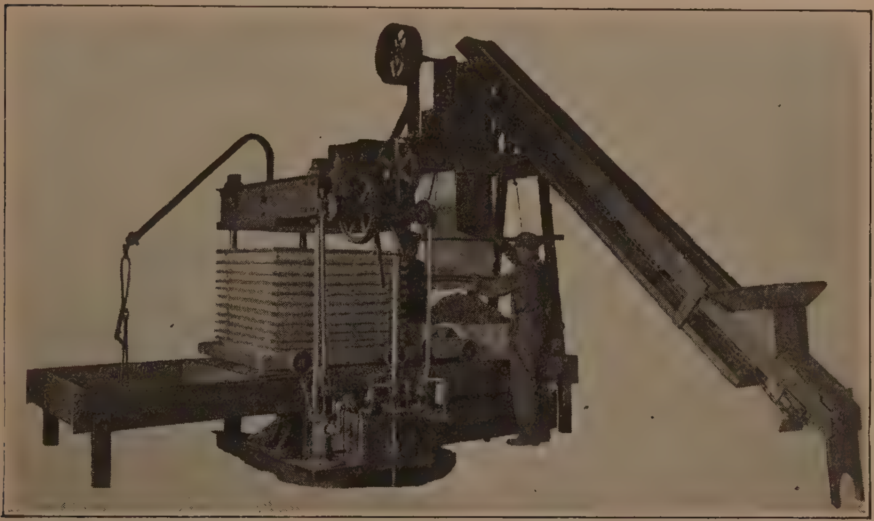


FIG. 47.—Large fruit crusher and hydraulic press. (*Courtesy, The Hydraulic Press Mfg. Co.*)

of which are set short knives extending the full length of the cylinder. Parallel with the cylinder is a set of upright knives or a fluted steel plate toward which the cylinder revolves. The fruit in passing between the knives of the cylinder and upright knives or plate is shredded or grated. The knives or plate are attached to heavy spiral springs which will permit hard objects, such as rocks, etc., to pass through the machine without seriously damaging it. The size of the gratings or the thoroughness of crushing can be regulated by adjusting the distance between the cylinder and the upright knives or corrugated plate (see Fig. 47 and 48).

Roller Crusher.—The roller crusher is used for grapes and is suitable for other soft fruits, such as berries, and in a modified form is in use for citrus fruits. It consists of two corrugated or fluted cylinders either of metal or hard wood, which revolve toward each other. They are placed in the same plane in a horizontal position and are surmounted by a hopper. The fruit is carried downward between the two rolls and is crushed by pressure. When used for grapes the crusher may be connected with a stemmer, which consists of a horizontal metal cylinder with a perforated bottom, through which the grapes are forced

by revolving paddles. The paddles are set at an angle on a shaft in such a position that the grape stems are carried out the open end of the stemmer opposite the crushing rolls. There is now in use in California a special type of a roller crusher with very large bronze rolls, used for citrus fruits.

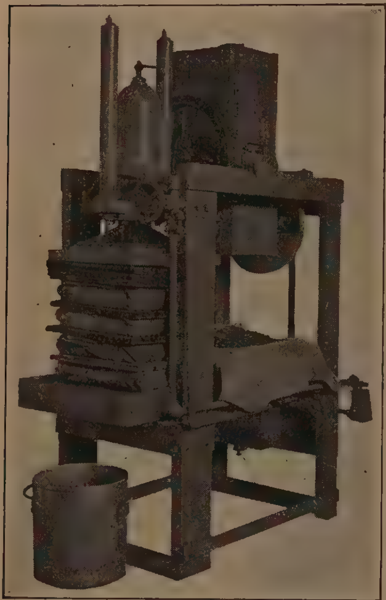


Fig. 48.—Fruit crusher and hydraulic press. (*In Fruit Products Laboratory, University of California*).

Pineapple waste is shredded in a specially designed machine developed for the purpose.

Pressing.—Juice is extracted from most fruits by presses of many different designs, in which pressure is obtained in several different manners.

Rack and Cloth Press.—Probably the most satisfactory press for general use is that known as the "rack and cloth press," which is used for apples. In this style of press the crushed fruit is placed in heavy cloths of coarsely woven heavy cotton fiber, to a depth of about 2 to 3 inches, and the edges of the cloths folded toward the center, as shown in Fig. 48. A wooden rack made of heavy, hard, wooden slats is placed on the folded cloth containing the fruit and a second cloth containing crushed fruit is placed on this rack. The process is repeated until the press is filled. The several cloths of fruits and the racks taken together are known as a "cheese." Pressure may be applied by any one of the methods described below, although the usual method is by hydraulic pressure.

Basket Press.—In the basket press, very generally used for grapes, the crushed fruit is placed in a heavily reinforced wooden basket of cylindrical form, as shown in Fig. 49.

Beam Press.—Pressure may be applied to either the rack and cloth press or the basket press in one of several ways, but the most simple method is by means of a long wooden beam weighted at one end. Pressure can be regulated by the amount of weight placed on the beam and by its length.

Screw Press.—The screw press represents the first improvement upon the beam press and is used most commonly in conjunction with a basket. The screw may be operated by a lever or by cog gears.

Hydraulic Press.—Hydraulic pressure can be applied by means of oil or water and a pump. The liquid is pumped into a heavy-walled

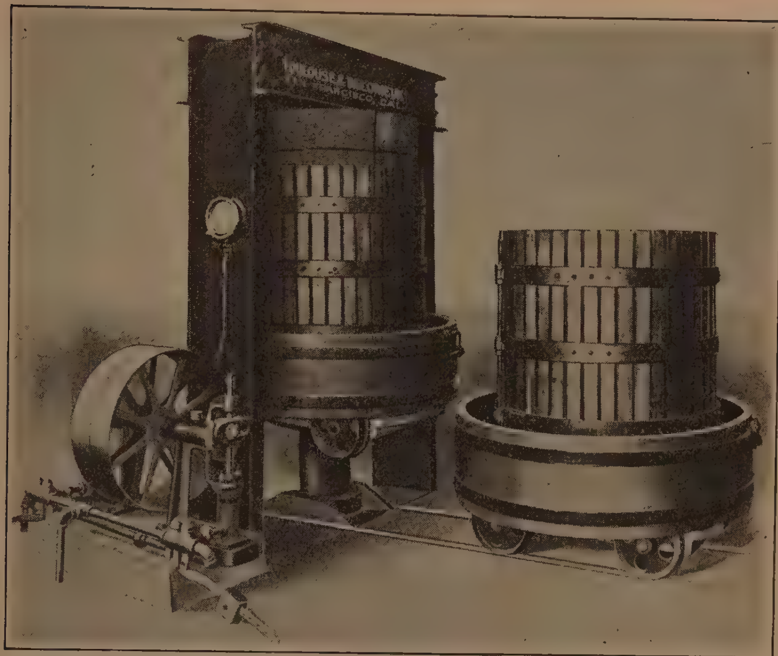


Fig. 49.—Basket press operated by hydraulic pressure. (*Courtesy, The California Press Mfg. Co.*)

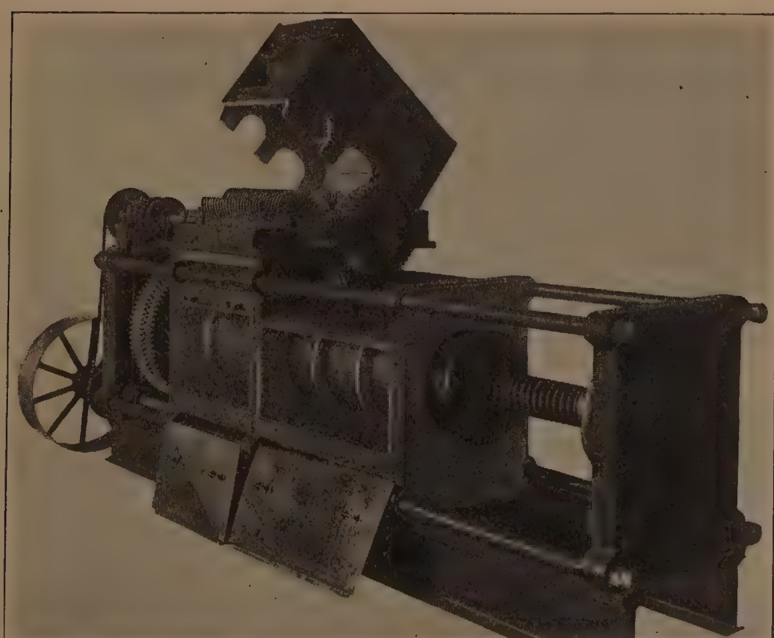


Fig. 50.—Crusher and continuous press. (*Courtesy, The California Press Mfg. Co.*)

"ram," or cylinder attached either to the top or the bottom of the press. The pressure that can be applied is in the ratio of the diameter of the pressure cylinder piston to that of the pump, and for very heavy pressures the diameter of the pump must be small and that of the cylinder large. Pressure must be increased at such a rate that the juice may escape from the cloths without subjecting the cloths to such pressure that they are ruptured.

Continuous Press.—All of the presses described above are discontinuous in action. Continuous presses are available, into one end of which the crushed, or in some cases the whole, fruit is fed, and to which pressure is applied and the pomace (pressed pulp) is discharged continuously at the opposite end of the press. The juice escapes through openings in the bottom of the press. In principle the press consists of a cone or cylinder with a perforated bottom, hopper and restricted adjustable opening at the end opposite the hopper and a heavy conical screw which revolves within the cylinder. The fruit enters the hopper at the large end of the press and is forced through the cone toward the smaller end. This press has proved fairly satisfactory for the pressing of lemons for the manufacture of citric acid and for pressing fermented crushed grapes, but is not desirable for use in pressing most fruits, because it tends to grind the fruit to a fine pulp, much of which passes through the openings in the bottom of the press with the juice (see Fig. 50).

METHODS OF PRESERVATION OF FRUIT JUICES

Several methods are in commercial use for the preservation of fruit juices. The most important of these are discussed below.

Pasteurization.—Pasteurization as applied to fruit juices means the destruction, by heat, of all microorganisms capable of increasing in the juice and of causing spoiling. It usually does not kill the spore-bearing organisms, such as *B. subtilis*, *B. mesentericus*, etc., but these organisms and most other spore-bearing bacteria as well cannot grow in acid fruit juices and consequently their presence is of no practical significance. Pasteurization of still (non-carbonated) juices need only be at such a temperature and for such a time that yeasts and molds are destroyed. Yeast is killed by heating for a few minutes at 145 to 150°F. and resistant mold spores will require in most cases a temperature of 175°F. for 20 minutes. Molds require oxygen for growth and for this reason heavily carbonated juices can be pasteurized safely at 150°F., which destroys yeast cells. Most still juices must be pasteurized at 175°F.; juices of high acidity may be pasteurized at a lower temperature, 160 to 165°F.

Effect of Carbon Dioxid.—Experiments have been made by J. H. Irish and the writer upon the effect of carbon dioxid upon pasteurizing, in which it was found that carbonating at from 10 to 60 pounds

pressure did not noticeably reduce the death temperature of typical fruit juice organisms, such as yeast, mold spores, *B. coli*, *B. subtilis*, etc. The carbon dioxid, however, prevented growth of surviving mold spores. It was found that 30 minutes pasteurization at 65°C. (149°F.) in all cases prevented subsequent development of yeast in samples heavily inoculated before pasteurization.

Bulk Pasteurization.—It is often necessary to store fruit juices in bulk in large glass carboys or in barrels to permit settling or shipment in bulk. Two types of pasteurizers, which may be designated as (1) continuous and (2) discontinuous, are used for this purpose.

The continuous pasteurizer consists of a single metal tube or series of small metal tubes, through which the juice flows and is heated to the desired temperature by a steam or hot water jacket. Block tin, aluminum and silver-lined copper are commonly used for the purpose.

Heating by Steam.—The use of steam is somewhat objectionable because it does not permit of very exact regulation of the temperature and is liable to cause scorching or overheating of the juice.

Heating by Water.—If the heating tubes of the continuous pasteurizer are surrounded by water it is possible to regulate the temperature very closely. The temperature of the water surrounding the heating tubes need not be more than 3°C. (about 6°F.) above the temperature of the juice, and therefore there is little danger of overheating the juice.

Discontinuous Pasteurizers.—The discontinuous pasteurizer consists of a steam-jacketed kettle, or of a tank equipped with steam coils, in which the juice may be placed and heated to the desired temperature. It is objectionable because it is liable to cause local overheating of small portions of the juice in contact with the heating surface, exposes the juice to the air and oxidation during pasteurization, and to prolonged heating with injury to color and flavor.

Flash Pasteurization.—Under usual factory conditions the juice in bulk pasteurization is passed while still hot directly into sterile barrels or large bottles for storage, and remains hot in the barrels for 24 hours or longer and in the bottles for 5 or 6 hours. This prolonged heating results in considerable injury to the flavor and the color of the product.

Chace[5] has devised a means of chilling the juice immediately after pasteurization by passing the cooled juice under aseptic conditions into sterile containers, preferably bottles, and sealing the containers with sterile corks or caps. Great care must be employed in order to avoid infection of the juice with mold or yeast, and it is doubtful whether the process will have wide application in factory practice. A temperature of 180 to 185°F. (about 82 to 85°C.) is used for a few seconds only, and therefore the juice suffers very little injury to flavor or appearance.

Pasteurization in Bottles and Cans.—After the juice has been filtered or otherwise treated to prepare it for bottling or canning, it is

sealed in the final container and pasteurized, usually by immersion in water, which is heated to the desired temperature and for the desired length of time. One form of bottle pasteurizer consists of a shallow wooden vat fitted with a steam coil and a perforated false bottom on which the bottles are placed in a horizontal position, covered with water and heated to the pasteurizing temperature.

In large establishments continuous pasteurizers are used in which the bottles of juice are carried by a basket conveyor progressively through baths of water of increasing temperature and through baths of water of decreasing temperature to cool the juice.

Heat may also be applied to the bottled juice by sprays of water circulated by a pump. The temperature may be regulated so that the bottles are heated gradually to the pasteurizing point and cooled slowly by gradually reducing the temperature of the water, so that breakage is reduced to a minimum.

Relation of Factory Sanitation to Pasteurization.—Investigations at the University of California have demonstrated that the temperature necessary for pasteurization varies with the mass of the infection of the juice with yeast or mold.

Therefore all possible precautions should be taken to exclude micro-organisms from the juice at all stages of the process. Press cloths unless washed immediately after use and dried at once will become "sour," *i.e.*, infected with large numbers of yeast cells and mold spores. The lines, pumps, tanks, filling machines and all other equipment that come in contact with the juice must be kept scrupulously clean and steam or hot water used frequently and generously in the cleaning and sterilizing of such equipment. Crushers are particularly liable to develop yeast and mold if not thoroughly cleaned after use.

Bottles, cans and bottle caps should be sterilized before use, caps in particular being a very prolific source of mold infection in bottled beverages.

Preservation of Fruit Juices by Chemical Preservatives.—Although it is not an ideal method of preservation, large quantities of apple juice are preserved with benzoate of soda. Other fruit juices are sometimes preserved with sulphurous acid.

Benzoate of Soda (and Benzoic Acid).—The active preservative principle of benzoate of soda is the benzoate radicle, not the sodium ion. The salts of benzoic acid are more readily soluble than the acid, and for this reason the sodium salt is employed in preference to the acid.

The percentage of sodium benzoate that may be used in the preservation of foods was at one time limited by pure food and drug regulations to $\frac{1}{10}$ of 1 per cent but at the present time more than this amount may be used, provided the label bears a statement giving the percentage con-

tained in the product. Fruit juices can, in practically all cases, be preserved satisfactorily by the addition of $^{15}/_{100}$ of 1 per cent of the benzoate. The benzoic acid exerts a selective action upon the organisms found in sweet cider, often preventing the growth of yeasts and molds, but permitting the development of vinegar and lactic acid bacteria.

Carbonating increases the toxicity of benzoic acid upon the spores of *Bacillus subtilis,* as shown by recent investigation by J. H. Irish on the carbonating of grape juice.

Sodium benzoate possesses a disagreeable "burning" taste that is readily perceptible in juice containing $^1/_{10}$ of 1 per cent of the benzoate.

Sulphurous Acid.—Fruit juice can be preserved for more than a year by the addition of $^1/_{10}$ of 1 per cent of sulphurous acid (1,000 milligrams per liter, or 1,000 parts per million), provided the juice is made from sound fruit and stored in clean containers at a temperature not above 60°F.

Sulphurous acid is very much more toxic to mold spores and vinegar bacteria than it is to yeast, in this respect differing from benzoic acid, which is more toxic to yeast than to vinegar bacteria. The following table summarizes the result of experiments made to determine the relative toxicity of sulphurous acid upon yeasts, molds and bacteria.

TABLE 39.—SELECTIVE ACTION OF SULPHUROUS ACID UPON THE MICROORGANISMS OCCURRING IN FRUIT JUICES

(Organisms given in number per cubic centimeters)
(*After Cruess*[12])

Organisms	Number of organisms in untreated juice	Number after 36 hours' exposure to 50 mg. SO_2 per liter	Number after 36 hours' exposure to 100 mg. SO_2 per liter	Number after 36 hours' exposure to 200 mg. SO_2 per liter	Number after 36 hours' exposure to 400 mg. SO_2 per liter
S. ellipsoideus (wine yeast)	20,000	640,000	2,000,000	310,000	36,000
S. apiculatus (wild yeast)	150,000	200,000	75,000	56,000	
Penicillium mold	120,000	40,000			
Bacterium aceti	310,000	14,000	300		

Fruit juice may be preserved temporarily (from several days to 2 or 3 weeks) with concentrations of sulphurous acid considerably less than $^1/_{10}$ of 1 per cent and small amounts of this preservative are often useful in preventing fermentation of juice during 1 or 2 days' settling after pressing, in order to aid in clearing. For this purpose 100 milligrams per liter (.01 per cent) of sulphurous acid is usually sufficient and does not noticeably affect the flavor of the product.

Disappearance of Sulphurous Acid.—Some of the preservative combines with the sugar and other compounds of the juice and in such a form is not perceptible to the taste and part of it either escapes into the atmosphere as SO_2 or is oxidized to sulphuric acid, H_2SO_4. The following table indicates the rate of disappearance of sulphurous acid from grape juice and the rate of conversion of free sulphurous acid into the combined form. Combined sulphurous acid has very little antiseptic value upon microorganisms, 6,000 parts per million of the combined form having less toxic action on yeast than 50 parts per million of the free sulphurous acid.

TABLE 40.—RATE OF DISAPPEARANCE OF SULPHUROUS ACID FROM GRAPE JUICE

(*After Bioletti and Cruess, Bull.* 230, *Univ. of Calif. Exp. Sta.*, 1912)

Time in hours	Total sulphur dioxide	Free sulphur dioxide
0.5	219	127
49.0	. . .	93
64.0	. . .	90
74.0	188	90
97.0	158	50
136.0	. . .	13
181.0	126	11

The presence of a very small concentration of sulphurous acid, *e.g.*, 50 to 100 milligrams of SO_2 per liter in fruit juice, greatly aids in the preservation of the fresh fruit flavor and color by reducing the tendency of the juice to oxidize. It cannot be used, however, in juice that is to be stored in tin or other metal containers since in contact with metal the SO_2 is reduced to H_2S with the development of a disagreeable flavor. Sulphurous acid can be removed by heating the juice to about 70°C. (about 160°F.) and passing through it a vigorous stream of air, or by passing a flow of steam through the juice under vacuum.

Sugar as a Preservative.—All fruit juices may be preserved by the addition of sugar or by increasing the natural sugar content of the juice by concentration. Such products are, however, fruit syrups and will be discussed fully in the chapter on syrups.

Preservation by Low Temperatures.—When stored at 32°F. (0°C.), the temperature ordinarily employed in the cold storage of fruits, fruit juices either become moldy or undergo fermentation and in order to prevent the growth of microorganisms it is necessary to use temperatures below 25°F.

In experiments at the University of California[14] it was found that grape juice, apple juice and berry juices could be held for at least 2 years at temperature of 10 to 15°F. (about 5 to 8° below 0°C.) without noticeable loss of flavor, aroma or color, where the juices were stored in sealed containers, such as lacquered tin cans or in bottles. The juices were not pasteurized.

It is believed that this method could be applied upon a commercial scale with marked increase in the consumption and popularity of unfermented fruit juices.

Recently fruit juices have been preserved by cold storage for shipment over a distance of 500 miles in glass-lined tank cars by precooling the juice to about 28°F. and placing it at once in well-insulated tanks of several thousand gallons' capacity each.

Preservation by Pressure.—Hite,[8] Giddings and Weakley found that grape juice in active fermentation could by sterilized by subjecting it to a pressure of 75,000 pounds per square inch for 30 minutes and by a pressure of 30,000 pounds per square inch applied for a somewhat longer time. Apple juice was sterilized by 60,000 to 80,000 pounds pressure per square inch applied for 30 minutes, and actively fermenting sugar solutions were sterilized by 60,000 pounds pressure in 30 minutes.

In their experiments a small collapsible tin tube was filled with the fruit juice or other liquid and the tube was sealed. The tube was then placed in a lead cylinder, which in turn was placed in a heavy-walled steel cylinder into which water or oil was forced by hydraulic pressure. In some of their experiments a pressure of 110,000 pounds per square inch was used.

The experimentors state that fruit juices preserved by this method were equal to the fresh fruit in flavor and general quality, and that it would be feasible to build a machine in which juice could be sterilized in containers of larger size than those used in their experiments.

Preservation with Carbon Dioxide.—Fruit juices have been successfully preserved by special methods of carbonating. In the Ruef process the fruit is first filtered through a porcelain filter to remove most of the yeast cells, and is then carbonated under aseptic conditions and bottled in sterile bottles. The method has not been applied commercially because of the great difficulty of completely excluding microorganisms.

In the Frank process, now in use for the preservation of "near beer," the liquid is placed in a heavy keg or other suitable container and subjected to a vacuum to withdraw most of the air from solution in the liquid. The liquid is then carbonated to a moderately high pressure, above 60 pounds per square inch, and is, after standing a short time, again placed under a vacuum and carbonated a second time. It is claimed that the repeated carbonating and treatment under vacuum destroys the microorganisms which would otherwise cause spoiling of the product.

THE FILTRATION OF FRUIT JUICES

Most fruit juices are improved in appearance by filtration or by other means of clarifying. The exceptions to this rule are the citrus fruit juices which are most popular in the cloudy condition.

The Bag Filter.—The simplest filter is that known as the bag filter, which is merely a conical bag made of heavy canvas, felt or other heavy cloth. Unless the juice is mixed with infusorial earth or other clarifying material it does not usually yield a clear juice. This filter is useful as a preliminary treatment for juice to be filtered through a more effective type of filter.

Fig. 51.—Large pulp filter for fruit juices showing filtering discs in place. (*Courtesy, The Karl Kiefer Co.*)

Pulp Filter.—The usual form consists of an upright copper or brass cylinder lined with a heavy tin or silver coating, and filled with several thick discs of compressed wood pulp or cotton fiber. Circular metal screens and metal plates are placed between the pulp discs and so arranged with regard to the juice supply pipe and outlet pipe that each disc acts as an individual filter. The juice is forced through the filter by gravity from a supply tank above the filter, or by means of a force pump. The filter mass or pulp must occasionally be removed, and washed thoroughly, and can then be formed into filter discs and used again. The clearness of the filtrate and rate of filtration depends to a large extent upon the pressure applied in forming the filter cakes. Thus, through heavily pressed discs filtration will be slower and the filtrate clearer than if the pulp is formed into cakes under low pressure.

For small-scale use a large suction funnel, in which a layer of pulp is packed as a filter mass, is satisfactory. It may be attached to a large wide mouth bottle and a suction pump.

Filters are also packed with short-fiber asbestos. The Seitz filter is of this type and consists of an upright cylinder in which is enclosed a screen coated with a layer of asbestos fiber. The clearness of the filtrate can be regulated by the length of the fiber used. Short fiber mixed with ground asbestos or infusorial earth is used for producing a brilliantly clear filtrate, while the longer fiber asbestos is used for coarse filtration. The asbestos may be washed and used repeatedly.

Filter Press.—The usual filter press consists of a series of metal or wooden plates between which are placed pieces of canvas or other heavy cloth, each piece of canvas and pair of plates acting as an independent filter, although all of the plates are fed from a common source (see Fig. 52).

In operating the filter press some of the juice is mixed with a small amount of infusorial earth, which collects on the surface of the filter cloths, forming a filter mass and effectively removing suspended matter from the juice.

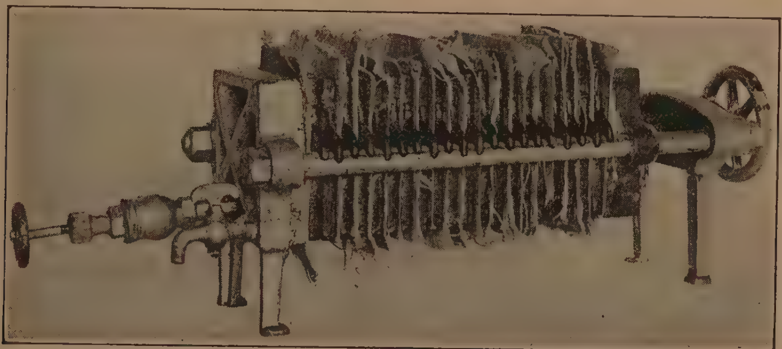


Fig. 52.—Small filter press with cloths and frames in place.

Effect of Preliminary Heating on the Filtration of Juices.—Fresh fruit juice is rather slimy in character and extremely difficult to filter. Preliminary pasteurization reduces the viscosity of the juice and 24 to 48 hours' settling usually results in the coagulation of much of the protein of the juice and its elimination by settling, together with a large proportion of the suspended, finely divided pulp.

Infusorial Earth As an Aid to Filtration.—Chace[5] has described a process of clarification of pomelo (grape fruit) juice in which the juice is pasteurized, allowed to settle several days, is drawn from the sediment, mixed with infusorial earth and filtered. Some infusorial earth imparts a disagreeable flavor to juice, but recently Caldwell[6] has found that heating the earth to dull redness volatilizes or burns the compound responsible for the undesirable change in flavor. He recommends the building up of a thick layer of the earth on a fine metal screen or heavy denim filter cloth in some form of filter press, and mixing with the juice to be filtered 5 or 6 pounds of the earth per 100 gallons. The producers of the infusorial earth are now in a position to furnish the incinerated earth in form suitable for the filtration of fruit juices.

Infusorial earth is mined as a white, friable and easily powdered rock, the principal deposit and mine being located at Lompoc, Cal. The rock is ground to a fine powder and separated into powders of different degrees

of fineness by sifting and air flotation, and is known to the trade as "Filter-Cel," "Featherstone," etc.

CLARIFICATION OF FRUIT JUICES BY SETTLING AND BY FINING

It is possible in certain cases to clarify fruit juices by settling, with or without pasteurization, as the juice may require, or by the addition of fining materials.

Settling.—Frequently fruit juices after pasteurization will become clear during storage, the length of storage necessary depending upon the variety of juice and other conditions. Thus, pomegranate juice will become clear within 24 hours after pasteurization, while grape juice usually requires several months' settling.

In the commercial manufacture of grape juice settling of the pasteurized juice greatly facilitates filtration by eliminating much suspended matter.

Use of Finings.—Some juices which do not settle satisfactorily during storage, and which are difficult to filter, can be clarified by the addition of a fining agent, which may be defined as a substance which, when added to the liquid to be clarified, will form a precipitate which settles and carries with it the finely divided particles responsible for the cloudy appearance. The fining materials most commonly used for fruit juices are egg albumen, casein, Spanish clay and infusorial earth.

Egg Albumen.—This is purchased in dry granular form and is dissolved in warm water by soaking and agitation. The temperature of the water must not be high enough to cause coagulation of the albumen and the best results are obtained with a 2 per cent solution. Red juice from Vinifera grapes (European varieties) normally requires about 100 to 150 grams of albumen (dry basis) per hectoliter (about 3⅓ to 5 ounces per 25 gallons) and Muscat grape juice requires about 200 grams of albumen per hectoliter. Preliminary tests with small lots (500 cubic centimeters each) of the juice should be made to determine the amount of finings required. The required amount of the finings solution is mixed with the juice and the whole is heated to a temperature of 160 to 175°F., coagulating the egg albumen, which settles rapidly during subsequent storage. Some of the albumen apparently remains in unstable solution for several days, but finally precipitates. The juice should be heated with the finings to a temperature several degrees above that to be used for the bottled juice, in order to avoid further coagulation of albumen and clouding in the bottle.

Casein.—Commercial casein is prepared from skim milk by precipitating the curd (casein) with dilute hydrochloric acid, separation of the curd from the whey and washing, drying and grinding the resulting casein. It is soluble in alkalies and is precipitated from solution by acids. For the clarification of fruit juices a 2 per cent solution is pre-

pared by soaking the casein in a small amount of ammonium hydroxide solution (concentrated ammonia diluted with 4 or 5 parts of water) and boiling until fumes of ammonia are no longer perceptible. The solution is diluted to 2 per cent casein content and is added to the juice as noted above for egg albumen. The acid of the juice precipitates and coagulates the casein and the coagulum usually settles completely within 24 to 48 hours after pasteurization. It is less likely than egg albumen to precipitate in clarified juice after bottling and it exerts considerable bleaching action on red juices.

Spanish Clay.—Spanish clay is a brown clay, rich in organic matter, and has been used in clarifiying fruit juices. It is ground in water to give a finely divided suspension, containing 10 grams of clay per 100 cubic centimeters (a "10 per cent solution"). This is added to the juice in amounts corresponding to 1,000 to 1,500 grams of the dry clay per hectoliter (about 35 to 50 ounces per 25 gallons).

Fruit juice may also be clarified by heating with 1 to 5 per cent of infusorial earth and settling.

Juices successfully clarified by means of any of the above fining materials can be filtered easily and yield brilliantly clear filtrates. However, in the clarification of fruit juices upon a commercial scale, filtration is in general the most satisfactory method.

BOTTLING OF FRUIT JUICES

Clear fruit juices are very attractive in glass containers, a fact which aids naturally in direct advertising to the consumer.

Preparation of the Bottles.—Bottles should be scrupulously clean and should be sterilized in live steam before use. Even a thoroughly rinsed bottle may contain a considerable number of mold spores and yeast cells. Large mechanical bottle soakers and washers are available which wash the bottles thoroughly in dilute lye solution and rinse them in water.

Caps.—The most common and least expensive closure for bottles is the Crown cap, long used for bottled soda water, beer and fruit juices. It consists of an outer metal disc, an inner cork disc, which rests against the top of the bottle and makes the seal, and of a shellacked paper disc between the cork and metal disc. This latter binds the metal disc and cork disc together. The cap is crimped to the bottle by compression in a Crown capping machine.

The Goldy cap is similar to the Crown cap but consists of two outer metal pieces, one of which is made of aluminum and can be removed from the bottle with the fingers.

Corks are sometimes used, particularly for heavily carbonated juices, but require the use of clamps during sterilization to prevent them from

being forced from the bottles, are more expensive than caps and not as attractive in appearance.

Caps or corks should be sterilized in steam before use in order to kill mold spores.

Filling Machines.—Bottles are usually filled by automatic or semi-automatic machinery. For the small-scale bottling of fruit juices a hand operated filler attached to a hose may be used.

Filling machines must be cleaned thoroughly after use in order to avoid development of mold and yeast during periods of idleness, and hose and other filling equipment should be thoroughly flushed with water and steamed before use.

GRAPE JUICE

The Chautauqua district of New York and the grape growing region of the Middle West produce most of the bottled grape juice in the United States. The total annual production for the United States is estimated at about 5,000,000 gallons.

Varieties of Grapes for Juice.—The Labrusca varieties are grown in New York and in the Middle West and the Vinifera varieties in California. The Labrusca varieties, such as the Concord, possess more acid and a more marked and characteristic flavor and aroma than the Vinifera varieties, and lack of distinctive character has made it difficult to market Vinifera juices.

Labrusca.—The Concord is the most popular of the eastern or Labrusca varieties, and most of the bottled grape juice on the market is prepared from this variety. The Pierce Isabella is also excellent for juice. Dearing[17] recommends it very highly and states that it produces a juice which is of more intense color and more easily clarified than Concord juice. He also recommends the Moore (Moore's Early), Catawba, Champion, Hartford and Worden.

Vinifera.—Of the Vinifera (European) grapes grown on a commercial scale in California, the Muscat (a white raisin grape) is the only one possessing a pronounced flavor. The Zinfandel, Petite Sirah and Alicante Bouschet, all commercially grown Vinifera varieties, can be used satisfactorily with the Muscat to furnish the necessary color.

Muscadine.—In the Southern States the Scuppernong or Muscadine varieties, grapes of pronounced flavor, are grown extensively. Dearing[17] has found the Thomas variety one of the best for juice because of its high acidity, flavor and sugar content. Others suitable for juice are the Latham, Mish, Carolina, James, Belle, Scuppernong and Luola. The Thomas, Scuppernong and Latham varieties produce white or yellow juices and red juices are obtained from the James, Mish and Luola.

Harvesting.—Labrusca varieties grown under eastern conditions should be harvested when they have reached full maturity and maximum

flavor and color. The same rule applies to the Scuppernong varieties.

The Muscat should be harvested when its juice has attained 22 to 23° Balling (test made on an average sample by a Balling hydrometer at 60°F.). The red wine grapes to be blended with the Muscat should be gathered before full maturity, in order that the juices may be of high acidity. This stage of maturity is 18 to 20° Balling for Petite Sirah, Alicante Bouschet, Barbera and similar varieties, and about 22° Balling for the Zinfandel variety. The last named variety is lacking in color if gathered below 22° Balling and acidity is furnished in this case by gathering the second-crop grapes with the first crop.

Storage.—It is usually necessary to crush the grapes within 24 hours after picking in order to avoid molding or fermentation. Hartmann and Tolman,[18] however, recommend storing of crates of Concord grapes in a cool, well-ventilated place for 24 hours or longer to permit mellowing and increase of the flavor and aroma of the grapes. In general it is advisable to crush as soon as possible after picking.

Boxes, crates and baskets must be clean and should not be permitted to become impregnated with fermenting and moldy juice.

Crushing and Stemming.—Red grapes are crushed and stemmed in the manner described earlier in this chapter since the stems impart a harsh flavor, if heated with the crushed berries.

Muscat and other white grapes are not heated before pressing and the stems may therefore be allowed to remain with the crushed grapes to aid in pressing.

Heating.—The color of red-juice grapes lies in the skins and is only slightly soluble in cold juice but dissolves quickly and readily in heated juice.

The crushed grapes are heated in steam-jacketed aluminum or glass-lined kettles, or the juice is drawn from the crushed grapes, is heated in a continuous pasteurizer and returned to the skins, the cycle being repeated until the desired temperature is attained.

It has been customary in commercial practice to heat the crushed fruit to 180 to 185°F., but Hartmann and Tolman[18] point out that 150°F. should not be exceeded, because of the extraction of an excessive amount of tannin from the seeds at higher temperatures. In experiments with Vinifera varieties in California the best results were obtained by heating the crushed grapes to 120 to 130°F. for 8 to 12 hours, although good results were obtained by heating to 160°F. for five minutes only.

Pressing.—In the Concord grape juice district, rack and cloth presses are used. In California the basket press is used.

The press cloths act as a filter during pressing and eliminate much of the fine pulp otherwise obtained in the juice.

The total pressure applied is about 100 tons for a press using 48 by 48 inch racks and corresponds to about 87 pounds per square inch on the racks and cloths. The time allowed for pressing according to Hartmann and Tolman[18] is about 85 minutes.

The pomace (press cake) is often broken up and pressed a second time.

The pomace from heated grapes is equal to about 15 per cent of the weight of the original grapes and contains about 60 per cent moisture and about 40 per cent solids. That from unheated grapes is usually about 20 per cent of the weight of the fresh grapes because pressing is less complete than with heated grapes.

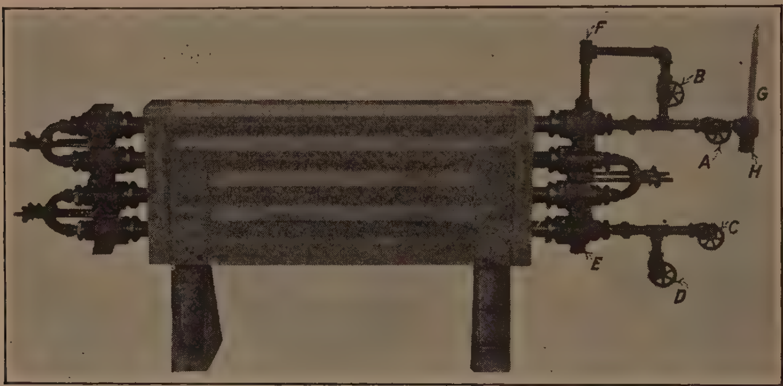


FIG. 53.—Continuous pasteurizer for heating fruit juices. (*Courtesy, The Hydraulic Press Mfg. Co.*)

The pomace is usually discarded, but is suitable for stock food or for the manufacture of such by-products as jelly, alcohol, salad oil, tannin and cream of tartar. The stems can be used as a source of tannin and tartaric acid, but are usually discarded.

Sterilizing.—The juice is strained through a screen or cloth to remove coarse pulp and in most factories is then heated to 180 to 190°F. and transferred to large glass carboys or stoneware jugs.

Heating is for the purpose of pasteurizing; the lower the temperature at which this can be safely accomplished the better the quality of the juice will be, but the temperature must be high enough to destroy mold spores, normally not less than 175°F.

The continuous pasteurizer is preferable because it is more convenient and does not permit as great a drop in temperature between the pasteurizer and storage container as occurs with discontinuous pasteurizers.

Carboys.—The carboys should be thoroughly steamed before use and should be hot at the time of filling. They are filled and then sealed immediately with corks sterilized in hot paraffin, which prevents entrance of air and microorganisms during storage. The corks should be covered with melted paraffin after the carboys are corked.

Barrels.—In California 50-gallon barrels are generally used as storage containers but are objectionable because they impart a woody taste to the juice, permit slow oxidation with loss of color and are difficult to seal against infection. Since juice remains hot in the barrels for 24 hours or longer, the result is a loss of flavor and color.

Storage.—Storage is for the purpose of permitting separation of excess cream of tartar—acid potassium tartrate, $KH(C_4H_4O_6)$—and settling of suspended solids, much of which represent coagulated proteins. The temperature of storage should be low, about 32°F., in order to hasten separation of cream of tartar and minimize danger of fermentation.

Hartmann and Tolman[18] have studied the changes in composition of Concord grape juice during storage, with the results given in Table 41.

TABLE 41.—CHANGES IN CHEMICAL COMPOSITION OF CONCORD JUICE DURING 4 MONTHS' STORAGE

(Grams per 100 cubic centimeter)
(*After Hartmann and Tolman*)

	Solids	Sugars (after inversion)	Non-sugars	Total acid as tartaric	Cream of tartar	Ash	Tannin and coloring matter
Before storage:							
Maximum	19.76	16.55	3.76	1.27	0.86	0.44	0.28
Minimum	16.99	13.38	3.06	0.98	0.64	0.34	0.15
Average	17.92	14.62	3.38	1.14	0.77	0.39	0.22
After storage:							
Maximum	19.18	16.30	3.07	1.10	0.63	0.32	0.22
Minimum	16.41	13.45	2.60	0.83	0.47	0.22	0.13
Average	17.39	14.52	2.87	1.01	0.53	0.27	0.18
Average loss	0.53	0.10	0.51	0.13	0.24	0.12	0.04

If the juice is not held under refrigeration, separation of the cream of tartar is slow and at least 6 months' storage is usually necessary. At 32°F., 3 or 4 months' storage is usually sufficient.

Carboys with straight sides, because they permit more satisfactory settling of suspended solids, are better than flask-shaped containers.

Racking.—The settled juice is separated from the sediment by syphoning by means of a U-shaped tube attached to a flexible rubber hose. The U-tube is inserted through the mouth of the bottle or barrel to a short distance above the sediment and gentle suction is applied to syphon the juice into a suitable container.

The sediment, consisting largely of cream of tartar, is strained through cloth to separate it from the juice and may be dried for sale to cream of tartar factories.

Filtering and Fining.—In eastern factories the juice is usually only roughly filtered through cloth, while in California it is usually fined with egg albumen or casein, as described earlier in this chapter and subsequently filtered.

Vinifera juices can be filtered very much more easily than Labrusca juices, since the latter are very rich in pectin and gums, hence viscous and difficult either to fine or filter.

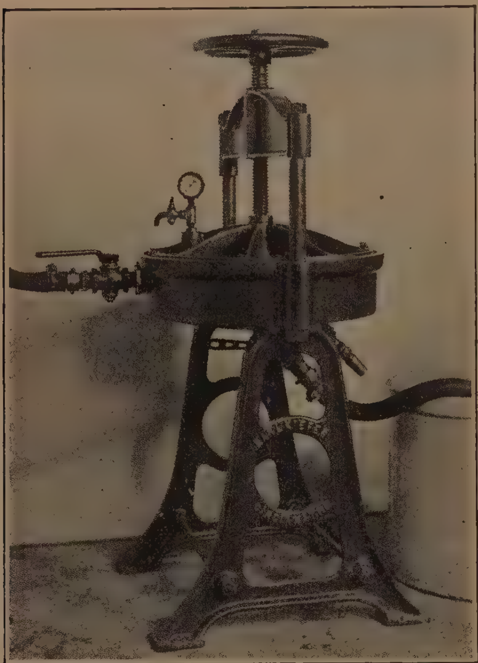


FIG. 54.—Small pulp filter for fruit juices.

Bottling and Pasteurizing. Grape juice is usually bottled as a still (not carbonated) juice, quart, pint and 4-ounce bottles sealed with Crown caps being the usual containers. Bottles and caps must be clean and should be sterilized in steam before filling in order to destroy mold spores.

The bottled juice is pasteurized in water, usually for 30 minutes at 175 to 180°F., and should be cooled after pasteurizing in order to check the deleterious effect of heat on the color and flavor of the juice.

Canning Grape Juice.—Grape juice has been canned in California, but has given serious trouble because of its tendency to cause perforation of the tin plate. In experiments made at the University of California it was found possible to prevent perforation by heating the juice to 160°F. for 15 minutes before canning. It was then canned hot in lacquered cans, sealed at once and pasteurized at 165°F. for 30 minutes. It acquires a slight "cooked flavor," but is otherwise satisfactory.

Quick Process for Bottled Juice.—It is possible to freeze fresh juice to a mushy mass of ice crystals and syrup by 24 hours' storage at 0 to 15°F. This treatment causes immediate separation of excess cream of tartar, which can be removed after allowing the frozen juice to melt. The juice can then be filtered and bottled. The entire process requires about 48 hours from crushing to bottling. Its use would greatly reduce the storage space and containers now employed in the sedimentation of grape juice.

Carbonating Grape Juice.—Grape juice can be carbonated in any of the standard types of carbonating machines. At the University of California the juice is placed in a heavy steel cylinder lined with tin and is agitated mechanically at room temperature in the presence of carbon dioxid gas under 20 to 50 pounds pressure. Forty pounds pressure gives an agreeable degree of carbonating.

The juice can also be carbonated by allowing it to flow downward against a stream of carbon dioxide in a narrow tube filled with glass beads, or by chilling the juice to 28 to 32°F. and passing a slow stream of carbon dioxid through it.

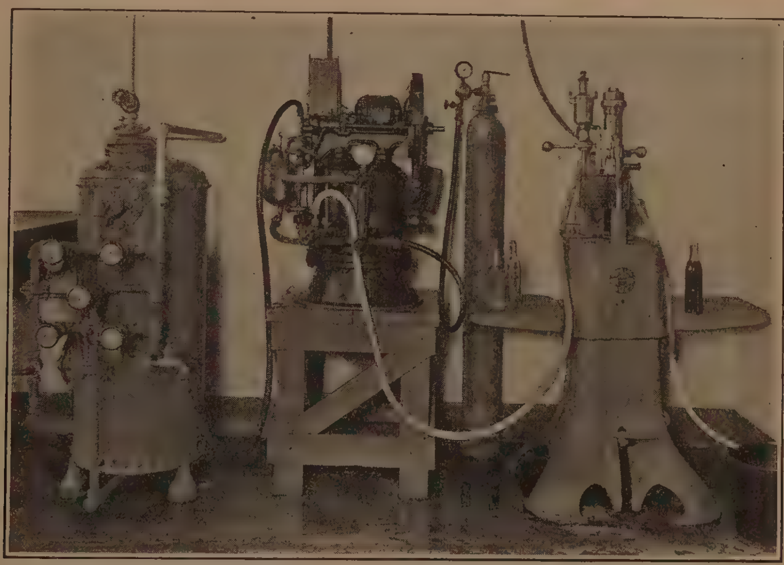


Fig. 55.—Small commercial size water softener, carbonator and bottling equipment. (*In Fruit Products Laboratory, University of California*).

Juice carbonated at 30 pounds or greater pressure can be pasteurized at 150°F. without danger of subsequent molding, while non-carbonated juice must be pasteurized at 175°F. The lower temperature of pasteurization of carbonated juice results in much less injury to flavor and color than occurs at 175°F. or above.

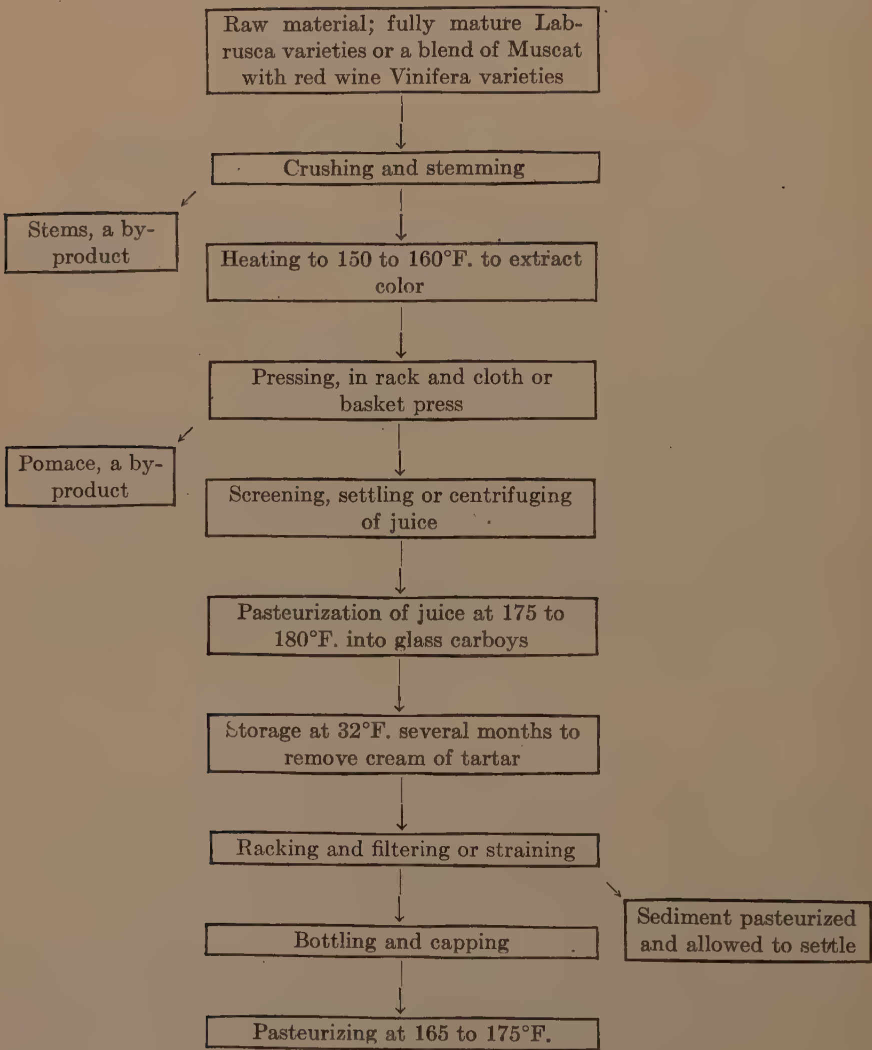
Probably the most satisfactory method of preparing carbonated beverages consists in concentrating the juice to a syrup, followed by mixing the syrup and carbonated water in the bottle with standard soda water bottling equipment.

Alcohol in Unfermented Grape Juice.—Hartmann and Tolman[18] found by the analysis of 104 samples of Concord juice that 44 per cent of the samples contained less than 0.1 per cent of alcohol; 77 per cent contained 0.2 per cent or less; and 90 per cent showed 0.4 per cent or less of

alcohol by volume. The remaining 10 per cent contained from 0.4 to 1.07 per cent alcohol by volume.

They found that freshly picked grapes contained very little alcohol and that most of the alcohol was formed by yeast during transportation, storage before crushing, and during crushing and pressing.

Flow Sheet for Grape Juice.—The following outline indicates in brief the steps in the usual method of preparing grape juice.



APPLE JUICE

Unfermented apple juice (sweet cider) is probably the most popular fruit juice sold in the United States, most of this juice being consumed

fresh, directly after pressing, or from barrels in which it is preserved with benzoate of soda. Benzoated cider is often of very poor quality and usually the flavor of benzoate is evident. The sale of cider preserved in this manner is, in the writer's estimation, the principal obstacle to expansion of the sweet cider industry.

Varieties of Apples for Juice.—Apple juice should possess a rich apple flavor and should be tart. The Winesap, Yellow Newton Pippin, Roxbury, Spitzenberg and Northern Spy are examples of good cider apples obtainable in commercial quantities.

Gore[2] has compared the quality of juices from a number of leading apple varieties after pasteurization and storage with the results given in Table 42:

Table 42.—Comparative Qualities of Juices from Several Varieties of Commercially Grown Apples

(After Gore)

Variety	Source	Quality of sterilized juice
Yellow Newton (syn. Albemarle Pippin)	Waynesboro, Va.	Juice very palatable; distinguished from the fresh only by the slight cooked taste and a little bleaching or lightening of color.
Ben Davis	Waynesboro, Va.	Quite unpalatable; lacking in distinctive apple flavor.
Winesap	Waynesboro, Va.	Very palatable; the fruity flavor somewhat impaired by sterilizing; slight bleaching noticeable; very little cooked taste.
Tolman (syn. Tolman Sweet)	Halls Corners, N. Y.	A very dark-colored, thick juice; very sweet and insipid.
Northern Spy	Halls Corners, N. Y.	Very fine in flavor; a fine rich juice, showing slight bleaching and hardly detectable cooked flavor.
Baldwin	Halls Corners, N. Y.	High in quality, very palatable; slightly bleached and with slight cooked flavor.
Roxbury (syn. Roxbury Russet)	Halls Corners, N. Y.	A heavy, rich juice, very palatable; slightly bleached and with very slight cooked flavor.

Gore[2] has also studied the effect of composition of the juice and its desirability as a beverage as shown in Table 43.

Gore concluded that apple juice to be most palatable to the average consumer should contain about 12 per cent or more of total solids and 0.5 per cent or more of total acid (as malic).

Table 43.—Composition of Unfermented Apple Juice from Different Varieties of Apples
(*After Gore*)

Variety	Total solids, per cent	Acid as malic, per cent	Reducing sugar, per cent	Total sugar, per cent
Yellow Newton (syn. Albemarle Pippin)	12.35	0.53	9.15	11.58
Ben Davis	12.05	0.48	7.86	10.05
Winesap	11.64	0.46	9.06	10.02
Tolman (syn. Tolman Sweet)	15.63	0.13	9.92	13.95
Northern Spy	14.90	0.61	8.52	12.82
Baldwin	14.31	0.63	7.33	12.22
Roxbury (syn. Roxbury Russet)	16.86	0.70	7.46	13.81

In addition to the proper proportions and concentrations of acid and sugar the juice must possess a distinctive and agreeable flavor. For example, the Ben Davis, while conforming in composition to Gore's requirements, yielded a juice of poor flavor and quality, because of its lack of distinctive apple flavor. The Yellow Newton, Winesap, Northern Spy, Baldwin and Roxbury and Kentucky Red all gave satisfactory juices.

Preparation for Crushing.—Although cider is usually considered a by-product and a means of utilizing culls, the raw material should be sound, free from rot, worms and fermentation. Apples to be used for cider should in all cases be thoroughly washed before crushing, because even under the best conditions they will carry considerable dust and are frequently contaminated with juice or pulp from spoiled fruit. The apples may be soaked by conveying them through a long tank of running water and the loosened dirt may be effectively removed by sprays. Undoubtedly a rotary tomato washer would be ideal for the washing of apples. Merely washing the apples in running water a short time as is done in some factories does not cleanse them effectively.

Sorting is even more important than washing in order that rotten and wormy fruit shall be removed.

Grating and Pressing.—The construction and operation of apple crushers and presses have been discussed earlier in this chapter.

Apple tissue is firm and tough and the cells possess heavy walls; consequently crushing or grating and pressing must be thorough in order to obtain a high yield of juice. Crushing too finely, however, causes the pulp to be too soft to press without danger of bursting the press cloths. Pieces ¼ to ⅛ of an inch thick are satisfactory. The rack and cloth rather than the basket press is best for apples because of the pulpy

nature of the fruit. The usual pressure applied to a press using racks 55 inches square is about 235 tons, or about 150 pounds per square inch.

The yield of juice from one pressing should be 160 gallons or more per ton. The pomace (press cake) may be broken up in a pomace picker (similar to an apple grating machine) and pressed a second time, but the second pressing of juice is of very dark color, of poorer flavor than the first pressing and is more suitable for vinegar than for sweet cider.

Clearing of Unfermented Cider.—It is frequently possible to clarify sweet cider by filtration directly after pressing, without preliminary

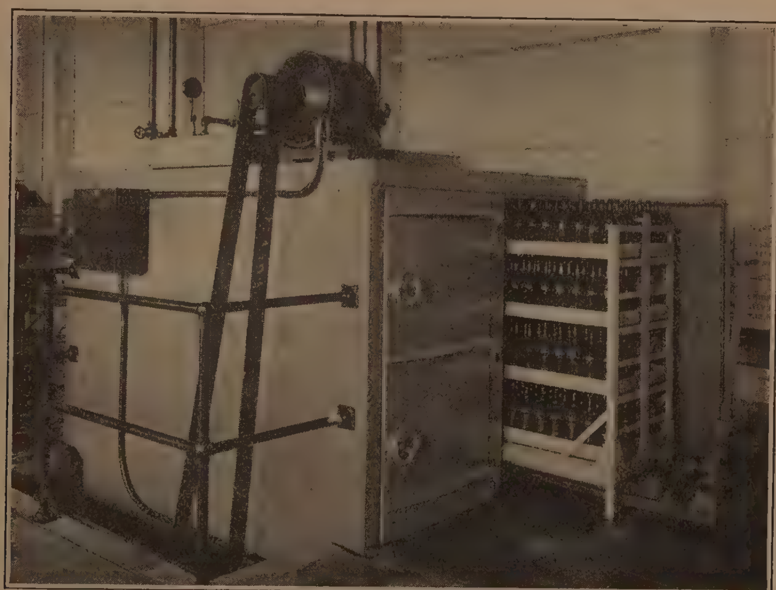


Fig. 56.—Discontinuous type of bottle pasteurizer. (*Courtesy of the Loew Mfg. Co.*)

heating to coagulate proteins, although it is usually desirable to pasteurize it before filtration by heating to 165°F. and cooling at once. The juice can be filtered as described for grape juice.

Filter presses fitted with wooden or heavily tinned forms are used in some apple cider factories, infusorial earth being mixed with the juice before filtration.

Cider does not respond well to clarification with finings such as egg albumen, casein and gelatin, but can be clarified very successfully by the addition of 1,000 to 1,500 grams of Spanish clay per hectoliter, as described earlier in this chapter.

Carbonating.—Cider is greatly improved for the average consumer by carbonating, and most of the bottled cider now on the market is lightly carbonated, *i.e.*, at 15 to 20 pounds pressure per square inch.

Idle breweries have been converted into cider factories in some apple producing localities, particularly in the Pacific Northwest, and the carbonating, bottling and pasteurizing equipment formerly used in these establishments for beer is now used successfully for cider.

Bottling and Pasteurizing.—These operations are accomplished as described for grape juice, although still (non-carbonated) cider is pasteurized at 165°F. (as compared with 175°F. for grape juice). Carbonated cider can be pasteurized at 150°F.

Canning Cider.—There is at present a fair demand for canned cider in No. 2½ and No. 10 cans. Plain tin cans are preferred to lacquered cans because of increased danger of perforation with the latter.

In one method the cider, after straining through cloth, is filled into the cans cold; it is heated in the cans in an exhaust box to 180 to 185°F. and the cans are sealed at once. No further treatment is given.

In a second method the cider is heated to 180 to 185°F. in a steam-jacketed kettle or continuous pasteurizer and is canned and sealed at once without further pasteurization.

E. H. Wiegand at Oregon Agricultural College recommends heating the juice to 160°F. for about 15 minutes to expel dissolved air and then canning and pasteurizing at 165°F. He states that this method prevents perforation and excessive corrosion of the tin plate and does not impart any appreciable cooked taste.

Distribution under Cold Storage.—In experiments made at the University of California unpasteurized cider in sealed cans retained the qualities of the fresh juice for more than 24 months when stored at 0 to 15°F. At 32°F. fermentation occurred. When stored in open containers at 0 to 15°F. the juice acquired a disagreeable musty flavor, caused by the absorption of odors from the atmosphere of the cold room.

LOGANBERRY JUICE

The preparation of loganberry juice is an important industry of the Pacific Northwest, where most of the juice is made by equipment installed in former breweries.

When the berries are fully mature and have attained their maximum color and sugar content, they are gathered in shallow trays. The fruit is soft and develops fermentation quickly after harvesting and for this reason it must be crushed within a few hours.

Juice Extraction.—The berries are crushed in a bronze crusher and pressed in a rack and cloth cider press. In some cases the berries are heated to 160°F. before pressing, to increase the yield and to obtain a juice of more intense color. Juice from unheated fruit contains less pectin and is therefore more easily filtered.

If the berries have not been heated before pressing, the juice is heated after pressing, to pasteurize it and to coagulate heat precipitable proteins. Silver plated or glass-lined equipment should be used in heating berries and berry juices. Aluminum corrodes rapidly and most other metals, including tin, injure the color.

Storage.—The juice is chilled by brine-cooled coils and stored in glass-lined or wooden tanks under refrigeration to permit settling until it is to be filtered and bottled.

Filtration.—Beer filters or pulp filters are used for filtering the juice. Because of its high content of gums and pectin it is more difficult than apple juice to filter.

It is not necessary to place the juice in cold storage to permit settling before filtration. It is feasible to filter the juice satisfactorily after 24 hours' settling at room temperature following preliminary pasteurization at 160 to 165°F. to coagulate proteins.

Addition of Sugar.—Unsweetened loganberry juice, after bottling and pasteurizing, usually develops a disagreeable astringent flavor and loses most of its color but the addition of a moderate amount of sugar prevents these undesirable changes. The added sugar gives a more pleasing beverage than the unsweetened juice, but sugar in excess of 50 per cent often causes the juice to form a jelly.

The sweetened filtered juice can be bottled and pasteurized as described for other juices.

The yield of freshly pressed juice is 160 to 180 gallons per ton, ripe berries yielding considerably more juice than the immature fruit.

Carbonating.—An excellent carbonated beverage for bottling purposes can be made from sweetened loganberry juice. One and one-half ounces of sweetened juice of 50° Balling is added to 8-ounce soda water bottles and carbonated water at 30 to 50 pounds pressure is added to fill the bottle, which is then crown capped and pasteurized at 150°F. for 30 minutes.

OTHER BERRY JUICES

Other berries also yield palatable beverages, particularly if sweetened and diluted with carbonated water.

Blackberry Juice.—Blackberry juice can be prepared as described for loganberry juice and the Balling degree of the juice should be increased to 50° by the addition of cane sugar to prevent deterioration of flavor and color. Unsweetened juice pasteurized and stored at room temperature loses most of its color and flavor. Because of its intense color it is very useful in fruit punches and sherbets.

Gore[1] reports yields of 66.9 to 69.6 per cent of juice from unheated blackberries and 74.4 to 80.9 per cent from blackberries heated before pressing.

Raspberry Juice.—Raspberries are of lower acidity than loganberries and blackberries; consequently their juice should not receive as much sugar.

Black raspberries yield a juice of more intense color and better keeping quality than red raspberries. The process of manufacture is the same as for loganberry juice.

CITRUS JUICES

Many attempts have been made to produce orange juice, lemon juice, pomelo juice and lime juice commercially.

In no case, known to the writer, has a thoroughly satisfactory beverage been produced. The principal difficulty is found in the tendency of all of these juices to develop a disagreeable "stale" or "musty" flavor and odor and to lose their fresh fruit flavor. There are many "orangeades," "orange" drinks, and "lemon" beverages on the market, but most of these are synthetic preparations composed wholly or principally of artificial color, sugar, citric acid and water, flavored with orange oil. In many cases the advertising of these synthetic preparations has violated the spirit of the Pure Food and Drug Regulations, both state and federal.

Orange Juice.—The Valencia variety yields a juice of better flavor and keeping quality than the Navel. Oranges harvested early in the season before the fruit is fully mature usually yield a bitter juice and fruit for juice should, therefore, be well ripened.

Extraction of Juice.—The juice can be extracted either by pressing the halved or crushed fruit in an apple press or by cutting the oranges in half and "spindling" them on a rotating porcelain, aluminum or bronze cone.

The first method yields a juice containing some oil from the skins, while "spindled" juice is practically free from oil. The juice obtained by pressing retains its flavor for a longer period than does the spindled juice and is injured less by pasteurizing. However, for soda fountain use the small spindling machines operated by a small, direct-attached, electric motor are ideal, because the juice is consumed immediately after extraction, and this drink is proving very popular in large cities. The California Fruit Growers' Exchange is distributing these machines at cost to soda fountains throughout the United States.

In the orange juice factory of the Exchange Orange Products Company of California the juice is expressed by passing the oranges through a set of two very large, slowly revolving fluted bronze rolls which express both the juice and the oil.

Vacuum Treatment.—The undesirable changes that occur during the storage of orange juice are in part due to oxidation. The dissolved air responsible for oxidation can be removed from the juice by subjecting it to a high vacuum (26 to 29 inches mercury) for about 15 minutes at

70 to 80°F. If it is then bottled and sealed in vacuo, it will retain its fresh flavor for a considerably longer time than if bottled in the usual manner. This method was first described by McDermott[3] in Bulletin 135 of the Florida Experiment Station.

Addition of Sugar.—The addition of cane sugar retards the undesirable changes in flavor and odor which normally occur in orange juice and most manufacturers of orange beverages add about 12 pounds of cane sugar per gallon to the freshly pressed juice, increasing the Balling degree to about 65°.

Concentrating.—C. P. Wilson, chemist for the California Fruit Growers' Exchange, has found that orange juice concentrated at temperatures below about 120°F. under a high vacuum (at least 28 inches mercury) retains its flavor and color fairly satisfactorily. The above company (a growers' organization) is now producing the concentrated juice commercially from cull oranges (see Chapter XVI).

Powdered orange juice has been prepared by the powdered milk spray drying process by the Merrill-Soule Company of New York. A palatable beverage is obtained when this dried juice is dissolved in water, but it is not equal to the fresh juice in flavor.

Gore[1] and others have attempted to prevent deterioration in flavor of unsweetened orange juice by carbonating. This treatment slightly retarded but did not prevent the undesirable changes.

Pasteurizing.—Orange juices and concentrates should not be pasteurized at above 165°F., because a temperature of 180 to 185°F. imparts a very pronounced "cooked" taste.

Freezing Storage.—In freezing storage, 0 to 15°F., orange juice in sealed containers retains its flavor very well for at least 6 months.

Yields.—A yield of approximately 100 to 110 gallons of juice is obtained from oranges of normal composition. The juice of ripe Navel and Valencia oranges in California is of approximately 11 to 14° Balling and of 0.8 to 1.5 per cent acidity expressed as citric.

Lemon Juice.—Lemon juice deteriorates more rapidly than orange juice, but responds more or less satisfactorily to the various treatments outlined above for orange juice. Lemon juice darkens rapidly after pasteurization, probably through oxidation, but the addition of a small amount of sulphurous acid or vacuum treatment and sealing in vacuo, as described for orange juice, greatly retard darkening.

The addition of sugar to form a heavy syrup, followed by treatment in vacuo to remove air, and pasteurization of the syrup sealed in vacuo have given fairly satisfactory results.

Powdered lemon juice prepared by the Merrill-Soule process retains its flavor more satisfactorily than does either the juice or the syrup.

The juice expressed from the whole fruit retains its flavor more satisfactorily than that obtained by spindling. The oil obtained from

the skin by the former method is a valuable addition to the juice or syrup.

Lime Juice.—Lime juice is prepared in large quantities in the West Indies. According to one description of the process of manufacture, the whole fruit is crushed and pressed and the juice is filtered and preserved in bottles with $\frac{1}{10}$ of 1 per cent of sodium benzoate. In some cases a small amount of sulphurous acid is added to check darkening of the color.

Most of this product possesses a disagreeable "stale" lime flavor.

Grapefruit Juice.—Only the juice from the pulp should be used and the oil from the peel should be excluded. Spindled juice is, therefore, to be preferred to pressed juice. It should be reinforced with cane sugar to about 30° Balling and to expel air should be vacuum treated or heated to 175°F. for 15 minutes before bottling. Juice not so treated is apt to darken. It can be bottled and pasteurized at 175° F. and retains its flavor very satisfactorily. Considerable quantities of the bottled juice have been prepared in Florida from the cull fruit. Grapefruit juice should have commercial possibilities as it is very popular as a breakfast drink.

Pineapple Juice.—This juice has been produced commercially in the Hawaiian Islands, but at the present time the industry is almost extinct. A nation-wide advertising campaign several years ago sold a large quantity of the juice, but "repeat orders" failed to materialize, because the juice possessed a disagreeable "stale" flavor.

The juice tends to darken and deteriorate in flavor in the bottle unless precautions are taken to exclude atmospheric oxygen by methods described elsewhere in this chapter. Bottling in carbon dioxide aids in the retention of color and flavor, and the addition of cane sugar aids materially in retaining the flavor.

On heating, pineapple juice gives a bulky, gelatinous precipitate that is difficult to remove by filtration. Gore[1] recommends heating of the freshly expressed juice to 85°C. (about 185°F.), settling for 1 hour, treatment in a centrifugal separator and filtration.

Pomegranate Juice.—Pomegranates yield a very attractive juice of deep purplish-red color and of pleasing flavor.

The juice may be extracted without obtaining too much tannin from the peel and pulp by cutting the fruit in halves or quarters and pressing in a rack and cloth press, but better results are obtained by pressing the whole, uncrushed fruit. If crushed in an apple or grape crusher and pressed, the tannin from the skins makes the juice undrinkable. The peel contains so much tannin that it may be used as a source of tannin for tanning leather.

The juice is easily clarified by heating to 175°F., cooling, settling 24 hours, racking and filtering. It should be sweetened by the addition of cane sugar to 30 to 35° Balling. It can then be pasteurized at 175°F. and retains its flavor very well for at least a year.

CARBONATED FRUIT BEVERAGES

Practically all of the so-called "fruit" soda waters on the market are prepared from artificially colored and flavored syrups. While many of these beverages are palatable, they contain in most instances little or no fruit juice. Investigations at the University of California have proved that fruit juices can be readily converted into syrups suitable for the use of soda water bottlers and soda fountains and that the consuming public prefers these beverages to those produced from the artificially colored and flavored syrups.

Preparation of the Syrups.—A detailed discussion of the preparation of fruit syrups will be found in Chapter XVI.

The juice is obtained from the fruit in the manner best suited to the fruit in question and as described earlier in the present chapter.

Berry juices, pomegranate juice and most citrus juices are converted into syrups by the addition of sugar; grape juice, apple juice and pineapple juice are concentrated by freezing and centrifuging or by vacuum pan concentration, as described in Chapter XVI.

The syrups are preserved by pasteurization or by cold storage. Berry syrups and pomegranate syrup are made to about 35 to 45° Balling, while grape juice is concentrated to about 60° Balling and other juices to about 55° Balling.

Carbonating and Bottling.—In using the syrup, about 1½ fluid ounces of the syrup are added to each soda water bottle of 8-ounce size. Carbonated water at 30 to 40 pounds pressure is added to fill the bottles. The bottles are sealed with crown caps at once and are then placed in a pasteurizer and heated to 150°F. for 30 minutes.

Standard soda water bottling equipment can be used for carbonating, bottling, and pasteurizing.

The cost of the fruit and sugar for the syrups used in an 8-ounce bottle of the carbonated beverage will in most cases not exceed 1½ cents. The beverages can be sold retail for not to exceed 10 cents per 8-ounce bottle and with fair profit to all concerned in the manufacture and distribution of the beverage.

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CHAPTER XVI

FRUIT AND VEGETABLE SYRUPS

Maple, sorghum and cane syrups have long been standard food products. Before the discovery of America the Indians used the concentrated sap of the maple as a food. The early white settlers quickly adopted the product and improved upon the crude methods of manufacture used by the aborigines.

Later, sorghum was planted in the Middle West and cane in the South to supply raw material for syrup. The manufacture of sorghum and cane syrups has become an important industry.

Fruit syrups are becoming popular for the preparation of beverages and soda fountain specialties and in certain cases provide an outlet for the lower grades of fruits. Starchy vegetables particularly sweet potatoes, have been investigated successfully as sources of syrup.

Types of Syrups.—There are a number of different types of syrups produced commercially.

Table Syrups.—Most table syrups are made by dissolving cane sugar or glucose, or a combination of the two, in water and flavoring the solution with an imitation maple flavor, vanilla or other suitable flavoring. In some sections of the United States, particularly in the South and Middle West, the sap of sorghum cane and sugar cane is concentrated to a heavy syrup for table use.

Cooking Syrups.—Molasses is a by-product of the sugar industry and is the mother syrup remaining after the crystallization of the sugar. It consists largely of a concentrated solution of invert sugar and dissolved solids which are uncrystallizable. Cane molasses is edible and is used extensively in cooking, particularly in the preparation of gingerbread, cookies, imitation brown bread, etc. Beet molasses is not edible.

"Sorghum molasses" is really a syrup rather than a true molasses, because it contains the whole cane juice from which sugar has not been crystallized.

Fountain and Bottling Syrups.—Under this heading are listed a great variety of syrups, most of which are wholly or in part synthetic preparations. Examples of the synthetic syrups are ginger ale syrup, Coca-Cola and similar syrups, imitation orange, lemon, lime, cherry and berry syrups. It is not our purpose to describe the manufacture of these synthetic preparations.

Real fruit syrups are now coming into greater favor. These represent in most cases fruit juices sweetened with cane sugar and preserved by pasteurizing or by sodium benzoate.

METHODS OF CONCENTRATION AT ATMOSPHERIC PRESSURE

Many syrups are prepared by concentrating a juice or sap or saccharified extract to a syrupy consistency. The method of concentration varies considerably, according to the character of the raw material and the size of the plant.

Open Concentrators.—The simplest form of concentrator is an open kettle, which may be heated by direct flame, by a steam jacket or by a steam coil.

Direct-fired Kettle.—This may consist of a cast-iron kettle placed over a firebox in which wood or other fuel is burned. Syrup produced in such an outfit is usually severely caramelized and darkened by overheating and by iron salts formed by the action of the juice on the iron.

Sorghum Pan.—A great improvement upon the direct-fired cast-iron kettle is the so-called "sorghum pan" used for maple, cane and sorghum syrups. This is a shallow rectangular pan (not more than 4 to 6 inches deep) made of copper, tin-lined copper, galvanized iron or very heavy tin plate and resting on a firebox. It is divided crosswise into sections with thin strips of metal and the sections are connected, giving in effect a zigzag path which the juice follows during the boiling process. The fresh sap or juice enters the firing end of the pan and the finished syrup is drawn off at the chimney end. The operation is continuous.

The pans vary in length from about 6 to 8 to about 15 feet, and can be lifted from the firebox to permit cleaning.

In using the pan the bottom is first covered with water and the juice to be concentrated is then allowed to run into the upper end of the pan to displace the water. As it flows through the zigzag channel of the pan it is concentrated by boiling. The rate of flow is so adjusted that syrup of the required density flows continuously from the outlet. A shallow layer of juice in the pan permits more rapid concentration than does a deep layer and for this reason gives a syrup of lighter color and with less scorched flavor.

During boiling the syrup must be skimmed frequently to remove coagulated protein, etc.

Some syrup manufacturers use two pans. In the first the juice is partially concentrated to cause clarification. The thin syrup thus obtained is then filtered and concentration is completed in the second pan.

Steam-heated Pans.—The steam heated pan evaporator is similar in principle to the sorghum pan and is a long, shallow, open wooden box lined with copper or tin in which the juice is boiled by a

closed steam coil, usually of copper. The coil extends the full length of the evaporator and is removable.

The coil is covered with juice to a depth not to exceed 1 inch above the coil. The method of operation is the same as for the sorghum pan, but there is less danger of scorching and the rate of concentration can be more accurately controlled than in the sorghum pan.

Steam-jacketed Kettles.—Steam-jacketed jelly kettles can be used for the preparation of syrups, but because the boiling process is necessarily prolonged the product is apt to be of dark color and scorched in flavor.

Kettles Heated by Coils.—Tomato puree kettles of glass-lined steel or wooden tanks fitted with copper flash coils are also used for the concentration of syrups, but are open to the same objection noted above for steam-jacketed kettles.

Concentration by Solar Heat.—Wet clothes dry rapidly when hung on a line in the open air on sunshiny days and drying is hastened if the day is windy.

These principles have been taken advantage of in a process for concentrating sugary liquids. The liquid is placed in a pan or tank; cheesecloth is dipped in the juice and hung above the tank to dry. In drying, water is removed by solar evaporation and a concentrated solution remains on the cloth. The cloth is, "wrung out," dipped in the juice and dried repeatedly until the liquid in the reservoir has attained the desired concentration.

This method is particularly adaptable to small-scale operations, yielding a syrup of brown or dark amber color and pleasing flavor, but to the writer's knowledge has never been used upon a large commercial scale.

Spray Process.—Milk is concentrated to a powder by forcing it in the form of a fine spray into a large chamber through which a current of heated air passes. The same principle and apparatus have been applied successfully to the concentration of some fruit juices to a powder.

In one form of spray-drying apparatus the liquid is sprayed into a large chamber into a current of heated air and the resulting powder is recovered in air-settling chambers or bag filters beyond the drying chamber.

In another machine the drying chamber consists of an inverted cone surmounted by a large cylinder, all of sheet metal, into which air heated by steam coils is forced tangentially by a powerful fan. The air is thus given a whirlwind motion within the chamber. The liquid is sprayed from a nozzle into the center of the "whirlwind," the droplets travel outward from the center toward the walls by centrifugal force and as they travel meet air of increasing temperature and decreasing humidity. When they reach the walls they have dried to a powder and settle into the conical bottom of the chamber as a fine dust.

The spray process can be used for drying some fruit juices, although it is usually necessary to mix with the juice glucose syrup, cane sugar or dextrine to prevent formation of a syrup after drying. In experiments made with grape juice with a milk-drying machine, it was found that, although the juice was dehydrated successfully, it melted at the temperatures used in drying (130 to 240°F.), because of the large proportion of fructose in the juice. On cooling, the product became solid and glass-like in appearance, but was very hygroscopic and became a syrup after a few hours' exposure to air.

Lemon juice and orange juice have been dried successfully by the Merrill-Soule Company.

Concentration by Freezing.—It has long been a common practice in the making of maple syrup to permit the sap to freeze. Ice separates in practically pure form, leaving a sap concentrated in proportion to the amount of ice that has formed. This principle has formed the basis of several methods of concentrating fruit juices and other solutions.

Gore Process.—In a process described and tested upon a commercial scale by Gore,[8] the juice is placed in a freezing room or in ordinary ice cans surrounded by cold brine, and is frozen to a mushy mixture of ice crystals and dilute syrup, or is frozen to a solid cake. It is then broken up by an ice crusher and is placed in the basket of a sugar centrifuge operated at moderate speed. The basket is a perforated cylinder attached to a vertical shaft and is surrounded by a heavy metal wall. The whirling of the centrifuge forces the syrup through the openings in the basket and the ice remains in the basket, where it may be washed free of syrup by a fine spray of water while the centrifuge is still in motion. The syrup collects in the chamber surrounding the basket and flows from the centrifugal by a suitably arranged outlet pipe.

The syrup is dilute and must be frozen and centrifuged at least once again to obtain a syrup of 50° Balling. The second freezing is carried out at a lower temperature than the first, because concentration lowers the freezing point. The writer has obtained satisfactory results by conducting the first freezing at 10 to 15°F. and subsequent freezings (usually three) at 0 to 5°F. A syrup of 54° Balling was obtained. This must be held in cold storage or pasteurized to prevent spoiling.

Juice concentrated by freezing possesses a richer fresh fruit flavor than that concentrated by any other known process, because the flavor and aroma of the fresh juice are not evaporated.

The method has been used commercially in the Hawaiian Islands at Pearl Harbor for the concentration of pineappple juice.

Energy Requirement.—The latent heat of freezing of water is 80 calories and of evaporation 537 calories, nearly seven times as much energy being required to evaporate as to freeze a unit quantity of water. Therefore, theoretically at least, it should be more economical to concentrate a

fruit juice by freezing than by the direct application of heat. In practice, however, the freezing process has proved more costly, because of its less direct use of energy, which involves development of mechanical energy, usually from burning fuel, and conversion of the mechanical energy to heat energy, with loss of energy in both operations, and because of the large amount of handling necessary in repeatedly freezing and centrifugalizing the juice and syrup.

Monti Process.—In the Monti process the syrup and ice crystals are separated by draining and a centrifuge is not employed. This process is in commercial use in Italy.

CONCENTRATION IN VACUO

Boiling in the open usually results in caramelization of the sugars of the liquid undergoing concentration and in excessive loss of flavor by evaporation and decomposition through heat. If the atmospheric pressure is to a large degree removed by placing the liquid under a vacuum, the boiling point of the liquid is reduced and much of the harmful effect of high boiling temperatures is avoided.

Relation of Boiling Point to Vacuum in Inches of Mercury.—Barometric pressure is usually expressed in inches of mercury. Vacuum degree is usually expressed in a similar manner, although reduced pressures (or "vacuum") is also often expressed in inches of mercury pressure or millimeters of mercury pressure. Thus, 2 inches pressure is approximately equal to 28 inches "vacuum." A perfect vacuum at sea level would be 0 inches positive pressure, or approximately 29.9 inches "vacuum."

At atmospheric pressure at sea level water boils at approximately 212°F., and in a perfect vacuum the boiling point is below the freezing point of water (32°F.); in fact, ice can be made by placing water under a very high vacuum.

At 29 inches vacuum, water boils at a temperature below 100°F., a temperature which results in no caramelization of fruit sugars and in very little injury to color and flavor. Table 45 gives the relation between vacuum and the boiling point of water Owing to the presence of dissolved solids, syrups boil in vacuo at temperatures somewhat above those given for water.

General Description of Vacuum Pans.—A commercial vacuum concentrating apparatus is commonly known as a vacuum pan.

Boiling Chamber.—The primary part of a vacuum pan is a vessel in which the liquid is heated. This is usually cylindrical, fitted at the bottom with a steam jacket and contains large steam coils or a tubular callandria to heat the liquid. A large outlet at the top connects to a vapor condenser and a vacuum pump (see Fig. 57).

The pan is often constructed of copper but may be made of glass-lined steel or of aluminum or other material resistant to the action of juices.

Walls.—The walls must be heavy in order not to collapse when a vacuum is applied. The bottom must be particularly heavy because the steam pressure in the jacket and the vacuum in the pan operate in the same direction. Thus a steam pressure of 50 pounds per square inch and a vacuum of 29 inches would be equivalent to about 65 pounds total strain per square inch.

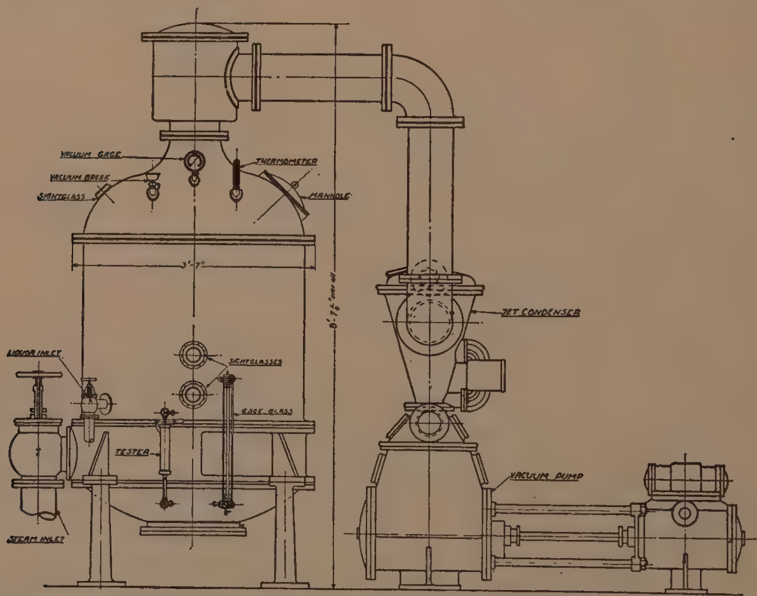

FIG. 57.—Sketch of vacuum pan with jet condenser and wet vacuum pump. (*Courtesy, The Oscar Krenz Co.*)

Traps and Valves.—The pan should be surmounted by an entrainment trap or dome to check the carrying over of liquid as a froth or spray. Sight glasses, inlet valves for fresh liquid, outlet valves for concentrated liquid and a suitable device for the removing and testing of samples during the boiling process are usually provided.

Callandria.—The most common heating device used in vacuum pans is the callandria. This consists of a large number of vertical steam-jacketed metal tubes resting near the bottom of the pan. The tubes are open at both ends and are joined by heavy metal plates, forming a honeycomb structure. The liquid fills the tubes and the space beneath the callandria and is heated by contact with the tubes.

For the concentration of delicately flavored fruit juices, high-pressure steam should not be used as a source of heat because of the danger of local overheating. The circulation of water at 110 to 150° or steam at less

than atmospheric pressure in the coils, jacket or callandria is less liable to cause injury. This plan has been followed in several commercial plants with marked success.

Vacuum Pumps.—Several methods of producing a vacuum (*i.e.*, removing air and non-condensable vapors) are in commercial use.

Wet Vacuum Pump.—A very common form of pump is the "wet" vacuum pump, which is usually a cylinder and piston pump of large diameter which not only pumps the non-condensable vapors and air, but also the condensed water vapor and the water from the jet condenser used in condensing the water vapor from the pan. Fig. 57 will make clearer the general design of such a vacuum pan and pump. The wet vacuum pump rarely gives in commercial practice a vacuum in excess of 26 inches mercury, which is not sufficient for the satisfactory concentration of fruit syrups.

Dry Vacuum Pump.—By means of a dry vacuum pump and a surface or barometric condenser it is possible to maintain under commercial operation a vacuum of 28 inches or more.

The dry vacuum pump is usually a rotary high-speed pump, the working parts of which turn in heavy mineral oil and which is similar to the small vacuum pumps in use in most analytical laboratories.

A condenser is interposed between the vacuum pump and vacuum pan in such manner that the pump cares only for air and other non-condensable gases which enter the pan through leaks or in solution in the fresh liquid.

Fig. 58 illustrates one method of using a dry vacuum pump.

Jet Pumps.—The water-jet vacuum pump is familiar to all students of analytical chemistry. This pump, in a much enlarged form, is employed in some commercial installations. Water flowing rapidly past an opening entrains air and other gases from the pan and produces a vacuum, which varies with the water pressure, temperature and volume of water used. It is not as satisfactory as the dry vacuum pump or the steam-jet pump.

A steam jet using steam under high pressure (100 lb. per square inch or more) is employed in a recently developed vacuum pump, which operates on the principle of the steam injector used to inject water into boilers, produces a high vacuum and is apparently satisfactory in commercial operation.

Jet Condenser.—A jet condenser consists of a chamber with baffle plates into which is forced a stream or spray of cold water, which comes in direct contact with and condenses the vapors from the vacuum pan. This method is efficient and economical in its use of water. The water used in the condenser and also the condensed vapors are removed by a wet vacuum pump or by means of a barometric system (see Figs. 57 and 58).

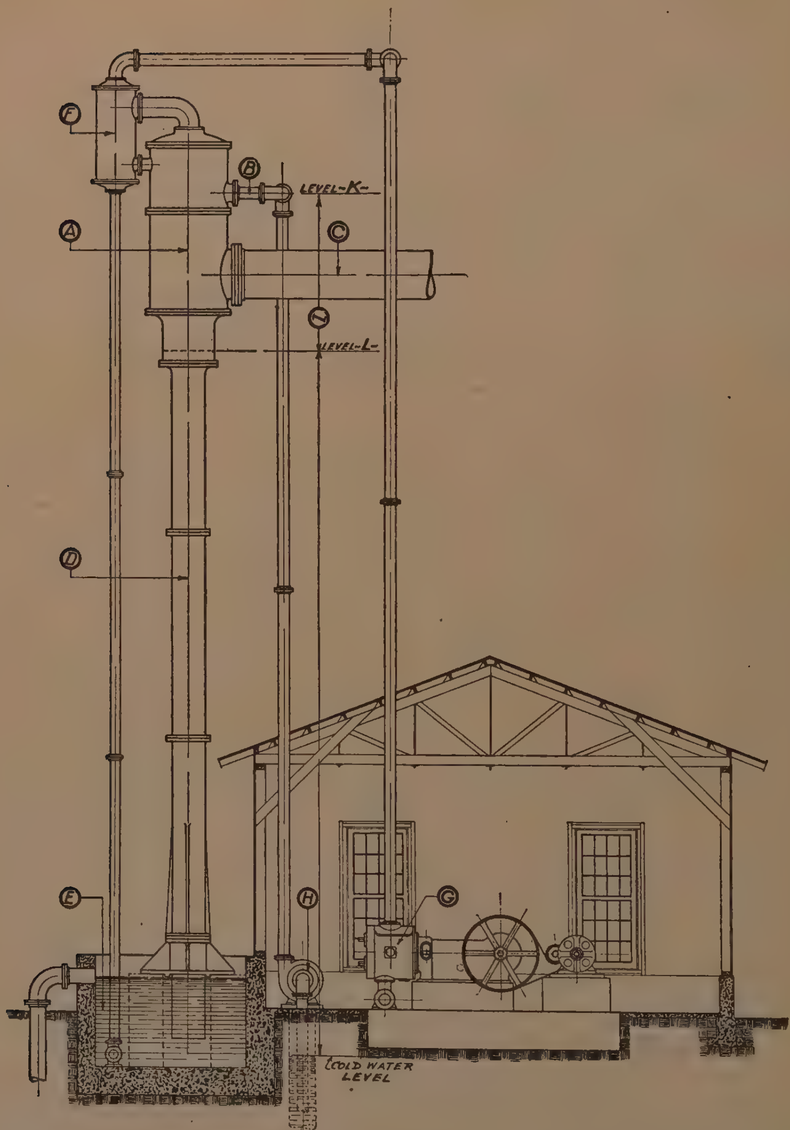

FIG. 58.—Sketch of dry vacuum pump installation. *A*, condenser head; *B*, inlet for condenser water; *C*, vapor inlet; *D*, barometric column; *E*, hot well; *F*, water separator; *G*, dry vacuum pump; *H*, water recirculating pump; *I*, working head of pump *H*; *K*, level of water injector; *L*, level of barometric column. (*After E. E. Horstmann, Fulton Iron Works*).

Surface Condenser.—The surface condenser consists of a water-cooled coil or series of hollow plates or pipes into which the vapors pass and are condensed by contact with the water-cooled walls of the condenser in much the same manner as vapors are condensed in a laboratory-size glass condenser of Liebig's pattern.

Barometric Leg.—The condenser may be attached to a "barometric leg" and "hot well," that is, a vertical pipe at least 31 feet high which dips beneath the surface of a tank or reservoir fitted with an overflow pipe (see Fig. 58). Water rises in the pipe in proportion to the vacuum applied to the system and flows from the hot well as rapidly as it collects in the

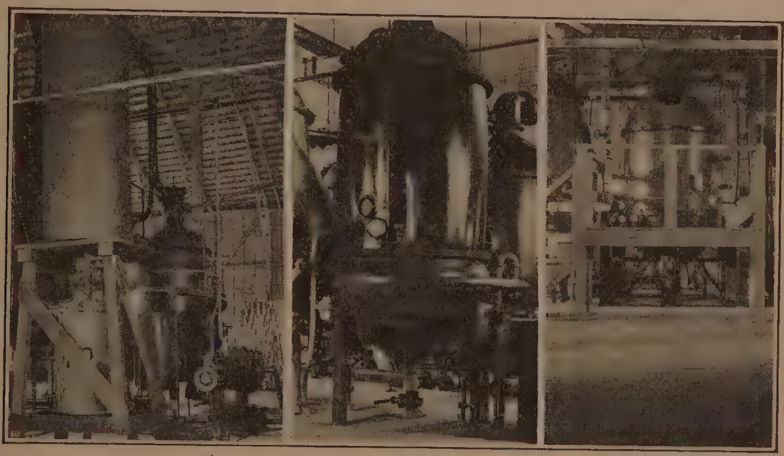

Fig. 59.—At left: Vacuum pan equipped with surface condenser and receiver. Center: Battery of vacuum pans used for concentrating grape juice. Right: Large vacuum pan showing jet condenser and barometric column.

barometric leg or standpipe. The condenser is usually of the water-jet type but if desired may be a surface-cooled condenser. Such a condenser and pipe is known as a barometric condenser because it is in contact with the atmosphere. The barometric column of water aids in maintaining the vacuum. The barometric standpipe or "leg" must be high enough to prevent flow of water from it to the vacuum pan.

Relation of Temperature of Condenser Water to Vacuum.—The lower the temperature of the condenser water the higher the vacuum it is possible to maintain in a given vacuum-concentrating system. Thus with condenser water at 32°F. it is possible to maintain a vacuum of 29.82 inches, provided, of course, a suitable vacuum pump is used. If the temperature of the condenser water is 90°F., it is possible to maintain a vacuum of only 28.58 inches of mercury, referred to atmospheric pressure of 30 inches of mercury.

The following tables give the relation between the temperature of condenser water and the maximum vacuum. These figures also repre-

sent the relation between the boiling point of water and vacuum in inches of mercury.

TABLE 44.—RELATION BETWEEN TEMPERATURE AND PRESSURE OF SATURATED STEAM

(*After E. E. Horstmann, "Steam Condensing Plants," published by Fulton Iron Works, Los Angeles*)

Temperature, degrees F. of condenser water	Pressure, pounds absolute	Vacuum in inches of mercury
32	0.0886	29.82
35	0.0999	29.80
40	0.1217	29.75
45	0.1475	29.70
50	0.1780	29.64
55	0.2140	29.56
60	0.2562	29.48
65	0.3054	29.38
70	0.3626	29.26
75	0.4288	29.13
80	0.5050	28.97
85	0.5940	28.79
90	0.6960	28.58
95	0.8130	28.35
100	0.9460	28.07
105	1.0980	27.75
110	1.2710	27.41
115	1.4670	27.01
120	1.6890	26.56
125	1.9380	26.04

NOTE.—The above vacua are referred to a barometer of 30 inches.

Water Required for Condensing.—The amount of water required for condensing a pound of steam varies greatly with the temperature of the condenser water and the vacuum degree maintained in the system. At 29 inches vacuum, and condenser water at 50°F., 90 parts of cooling water are required to condense 1 part by weight of water vapor. Less water is required at lower vacua.

Considerably less condensing water is required for a vacuum-concentrating system using a dry vacuum pump than for one using a wet vacuum pump. This is true because when the dry vacuum pump is used the difference in temperatures of the condenser water and the vapors evolved in the pan can be less. In the use of the wet pump there must be a considerable difference in temperature between the condensate and the vapors from the pan in order that the desired vacuum may be maintained.

Heat Requirements.—It is a popular misconception that a great deal less heat is required to evaporate water under a vacuum than at atmospheric pressure, but the heat required in either case is that required to heat the liquid to the boiling point, plus the latent heat of vaporization of water. The latter quantity is several times greater than the former and is practically the same whether evaporation occurs at atmospheric pressure or in vacuo. Therefore, the principal saving in heat in evaporating in vacuo is in that used to heat the liquid to the boiling point. Thus if the boiling point is 212°F. at atmospheric pressure and 105°F. in vacuo, and the initial temperature of the liquid is 60°F., the liquid must be raised 152°F. if boiled in the open, and only 45°F. if boiled in vacuo. The saving in this case would be 107°F., or in the evaporation of 1 pound of water, 107 British thermal units (B.t.u.), or in the evaporation of 1 gram of water, about 59 calories.

A British thermal unit is the amount of heat required to raise 1 pound avoirdupois of water 1°F. A small calorie (one cal. is the amount of heat required to raise 1 cubic centimeter (1 gram) of water 1°C.; a large calorie (one cal.) is the heat necessary to raise 1 litre of water 1°C. One B.t.u. equals 0.252 large calories (252 small calories).

The latent heat of vaporization of water at atmospheric pressure at 212°F. is 970.4 B.t.u. and at 105°F. is 1,032.9 B.t.u. The following table shows the relation between the latent heat of vaporization (B.t.u.'s necessary to change 1 pound of water into steam) and the temperature and vacuum at which vaporization takes place.

TABLE 45.—RELATION BETWEEN TEMPERATURE OF VAPORIZATION, LATENT HEAT OF VAPORIZATION OF WATER AND BOILING POINT

(*After The Lillie Evaporator Co. Tables*, 1918)

Temperature F.	Vacuum inches mercury	Latent heat, in B.t.u.
32	29.8191	1,073.40
40	29.7516	1,068.90
50	29.6365	1,063.30
55	29.5631	1,060.50
60	29.4770	1,057.80
65	29.3760	1,055.00
70	29.4590	1,052.20
75	29.1250	1,049.40
80	28.9680	1,046.80
85	28.7880	1,044.00
90	28.5800	1,041.20
95	28.3410	1,038.40
100	28.0700	1,035.60

TABLE 45.—RELATION BETWEEN TEMPERATURE OF VAPORIZATION, LATENT HEAT OF VAPORIZATION OF WATER AND BOILING POINT (*Continued*)

(*After The Lellie Evaporator Co. Tables*, 1918)

Temperature F.	Vacuum inches mercury	Latent heat, in B.t.u.
105	27.7590	1,032.90
110	27.4040	1,030.10
115	27.0050	1,027.30
120	26.5530	1,024.40
125	26.0400	1,021.60
130	25.4800	1,018.81
135	24.8300	1,015.90
140	24.1100	1,013.10
150	22.4200	1,007.40
160	20.3200	1,001.60
170	17.7700	995.80
180	14.6700	989.90
190	10.9300	983.90
200	6.4700	977.90
210	1.1600	971.60
212	0.0000	970.40

Multiple-effect Vacuum System.—In sugar factories the sugary liquids are concentrated in multiple-effect vacuum pans, that is, several pans, usually four or five, which are connected in series in such a manner that the vapors from the first pan pass through the heating system of the second and the vapors from the second pass through the heating system of the third, and similarly for the remaining members of the system.

The boiling point of the liquid in pan 1 is usually above 212°F., in 2 slightly less than 212°F., and the temperature in each succeeding pan is sufficiently less than in the preceding pan, that the vapor from the latter will cause boiling to take place. By this method the heat applied to vaporize the liquid in pan 1 is used repeatedly in succeeding pans, by the simple device of maintaining different degrees of vacuum in the different pans. This system has been used in the concentration of sorghum syrup on a large scale and in sugar factories. Because of the high temperature necessary in the first pan, the writer doubts the applicability of this system to the evaporation of fruit juices.

FRUIT SYRUPS

The manufacture of syrups affords a means of utilizing a considerable portion of cull and second-grade fruit of sound condition.

Grape Syrup.—Grape syrup may be prepared from any variety or color of grape, but the process of manufacture will vary with the character of the finished product and the proposed utilization. The grapes should be fully mature in order to be of maximum sugar content and optimum flavor.

Preparation of the Juice.—White grapes are crushed but are not heated before pressing. Red grapes are crushed, stemmed and heated to 120 to 160°F. to extract the color from the skins. The grapes are then pressed as described for the preparation of grape juice for bottling. The juice should be clarified by filtration after heating to 160°F. to coagulate proteins.

Grape Syrup for Beverage Purposes.—Grape syrup to be used in beverages must possess a marked fresh grape juice flavor and deep red color. Any of the Labrusca or Scuppernong varieties used for red grape juice, or a blend of equal parts of red Vinifera juice, such as Zinfandel, Petite Serah, etc., with Muscat or other highly flavored white Vinifera juice can be used.

The most common method of concentration is in a vacuum pan under a high vacuum (at least 28 inches mercury). The pan must be constructed of material which will not injure the color or flavor of the juice. Direct contact with copper, tin, iron or zinc causes the red grape color to turn brown or to precipitate, and if the action is prolonged will impart a metallic taste. A glass-lined pan with steam jacket and flash coil of aluminum or other metal insoluble in the juice is ideal for the purpose. Copper is less objectionable than tin.

Concentration by boiling in vacuo results in loss of considerable of the grape aroma, but it is possible to collect the distillate and by fractional distillation in vacuo to concentrate it to a small volume and return it to the syrup. The Seralian process depends on this principle.

It is also feasible to concentrate part of the juice by the freezing method described earlier in this chapter and to obtain thereby a highly flavored syrup, which can be blended with syrup concentrated by the usual vacuum pan method. Muscat syrup produced by the freezing method is particularly rich in flavor and desirable for blending purposes.

Grape Syrup for Table Use.—Excellent table syrup can be prepared from clear grape juice by concentrating the juice in a vacuum under 28 to 29 inches vacuum. If made from red grapes it will be of deep purplish-red color and of a rich, berry-like flavor and is very desirable for table use.

It is possible to neutralize all or most of the acid of grape juice by the addition of calcium carbonate or calcium hydroxide. Insoluble calcium tartrate is formed and can be separated from the juice by settling, racking and filtering. The calcium tartrate forms most readily at or near the boiling temperature and is most insoluble at low temperatures. There-

fore, the juice should be heated to facilitate the reaction and should be allowed to cool before filtration. Not all of the acid should be neutralized. The juice should retain about 0.1 per cent acidity (as tartaric) after neutralization. Complete neutralization results in darkening of the syrup and renders it more liable to injury in flavor during concentration.

The partially neutralized juice can be decolorized by the use of animal or vegetable decolorizing carbon. A light-colored syrup of neutral flavor can then be produced by vacuum pan concentration.

Grape and other fruit syrups in which part of the acid has been neutralized or from which both acid and color have been removed must compete with cheap table syrups, and therefore, usually do not afford a profitable means of utilizing grapes or other fruits.

Preservation of Grape Syrup.—Grape syrup is best preserved by pasteurization in bottles or enamel-lined cans, accomplished by heating the syrup to 165°F. in sealed containers for 20 minutes.

The pasteurized syrup should be cooled to room temperature as rapidly as possible to prevent loss of flavor and color by prolonged heating, since grape syrup rapidly darkens at temperatures above 130°F.

If the concentration of the syrup exceeds 68° Balling it may usually be stored for several months without danger of fermentation; but crystallization of the sugar is apt to occur in such highly concentrated syrup.

The syrup may also be satisfactorily stored at 26°F. or lower temperatures. At 32°F. molding often occurs.

The use of sodium benzoate as a preservative for fruit syrups should be avoided.

Crystallization of Sugar in Grape Syrup.—White grape syrup will usually become a semi-solid mass of dextrose crystals at concentrations above 65° Balling. Syrup from red grapes heated before pressing does not exhibit this tendency as frequently as the white syrup, because of the inhibiting effect of gums and pectins extracted by the heating of the crushed grapes. The addition of dextrine to the syrup retards, or, if used in high enough concentration, prevents the crystallization of dextrose in white syrup.

Separation of Cream of Tartar.—Grape juice is a saturated solution of cream of tartar—acid potassium tartrate, $KH(C_4H_4O_6)$—and concentration of the juice to a syrup causes the excess cream of tartar to crystallize. Much of the cream of tartar separates as a fine-grained "sand" during concentration, but a considerable proportion crystallizes only very slowly after concentration. In using the syrup for some purposes the presence of the cream of tartar is not objectionable, but generally the syrup should be as nearly free from the crystals as possible. If the syrup is stored for several weeks the excess cream of tartar separates almost completely.

Yield of Syrup.—Grapes if thoroughly crushed and pressed yield from 160 to 185 gallons of juice per ton. The pomace can be treated with hot water and pressed to recover most of the residual juice, amounting to 15 to 30 gallons per ton of grapes.

The yield of syrup from a given volume of juice varies with the per cent of total dissolved solids (Balling degree) of the juice in accordance with the following formula

$$G = b\,\frac{b \times s}{B \times S} \times g$$

G = gallons of syrup.
g = gallons of juice.
b = Balling degree of juice.
s = specific gravity of juice.
B = Balling degree of syrup.
S = specific gravity of syrup.

By application of this formula it will be found that 100-gallon lots of juices of 18, 19, 20, 21, 22, 23, 24 and 25° Balling will yield 22.5, 23.9, 25.2, 26.6, 28, 29.4, 30.8 and 32.1 gallons respectively of syrup of 65° Balling.

Apple Syrup.—In the past, apple syrup has been used almost exclusively for culinary purposes. If properly prepared, however, it is suitable for soda fountain use and the preparation of bottled beverages.

Preparing the Juice.—If the syrup is to be used for beverage purposes the apples should be of suitable quality for making sweet cider. For preparing boiled cider for culinary purposes, peels, cores and apples of all varieties may be used.

The raw material must be sound, carefully sorted and washed. Crushing and pressing are conducted as in preparing juice for bottling.

The juice should be made as clear as possible before concentration. This can be done by heating it to 160°F., cooling and filtering.

Concentration.—Gore[8] has demonstrated that an excellent concentrated cider suitable for beverage purposes can be prepared by the freezing method described earlier in this chapter.

Concentration in vacuo at 28 to 29 inches vacuum in a pan heated with water at 120 to 150°F. also yields an excellent product. If concentration is carried beyond 60° Balling, jelling is apt to take place because of the pectin present in the juice.

The usual method of concentration is by boiling in a shallow, open wooden box fitted with a copper steam coil, the operation of which is similar to that of a sorghum pan. A direct-fired sorghum pan can also be used. In either case the syrup produced is only suitable for table use or culinary purposes.

Preservation.—Boiled cider usually keeps without sterilizing. Vacuum concentrated syrup or that made by the freezing process and

of 50 to 60° Balling should be pasteurized at 165°F. in order to prevent fermentation or molding.

Pear Syrup.—Pear syrups similar in composition to concentrated apple juice can be prepared. These possess a rich, baked-pear flavor and are suitable for table or culinary use.

Orange Syrup.—Orange syrup is in great demand for the preparation of carbonated beverages.

Sugar Syrups.—Usually the juice is extracted by crushing and pressing the entire fruit. The juice should be "flask pasteurized," *i.e.* heated to 180 to 185°F. for a few seconds before conversion into syrup in order to destroy the oxidase responsible for changes in flavor during storage of the syrup. The usual method of preparing the syrup is by adding 12 pounds of sugar per gallon. The syrup should be placed under 28 to 29 inches vacuum at room temperature for 25 to 30 minutes to remove dissolved air and should then be sealed airtight in completely filled bottes, lacquered cans or jugs. The presence of air in syrup or container causes the oil to oxidize and become "terpeney" in flavor.

Syrup is also prepared commercially by extracting the juice and yellow pulp on revolving aluminum, bronze or porcelain cones, and oil from the skins is excluded. The juice is strained through a coarse screen and sugar to increase the Balling to 65° is added, together with benzoate of soda $\frac{1}{10}$ of 1 per cent. Lemon juice or citric acid may also be added.

All orange syrups tend to deteriorate in flavor during storage.

If the product is pasteurized at 165°F., sodium benzoate can be omitted from orange syrup.

Vacuum Concentration.—C. P. Wilson, chemist for the Exchange Orange Products Company, of San Dimas, Cal., has found that orange juice can be concentrated to a heavy syrup in a glass-lined vacuum pan successfully, provided a high vacuum (at last 28 inches) is maintained. This syrup is now in commercial use by soda water bottlers and fountains. The vacuum-concentrated syrup requires the addition of no sugar and, therefore, uses much more fruit per gallon of syrup than the syrup prepared from juice and cane sugar.

Other Citrus Fruit Syrups.—The principles and methods discussed above in connection with orange syrup also apply to the preparation of syrups from other citrus fruits. Lemon syrup tends to deteriorate more rapidly in flavor than orange syrup, while grape fruit syrup retains its flavor very satisfactorily.

Berry Syrups.—Berry syrups are used extensively in soda fountains for carbonated drinks and for dressings for ice creams. They should find wider use than is the case at present, for carbonated bottled drinks and in the household in the preparation of fruit punch, gelatin desserts, cake fillings, etc.

The berries should be thoroughly ripe, free from mold or fermentation and should be carefully sorted and washed. Strawberries need not be hulled.

The berries are crushed, heated to about 160°F., pressed and the juice filtered. Sugar can then be added to increase the Balling degree to about 60 to 65° for strawberry and raspberry juices. Loganberry, currant and sour blackberry syrup will often jelly if the sugar concentration exceeds 50° Balling.

If the syrup is to be stored at room temperature, it should be pasteurized in bottles or enamel-lined cans.

Excellent syrups, more concentrated in flavor and color than those described above, can be made by the freezing process. The Balling degree of the juice should be increased to about 20 to 25 per cent by addition of sugar before freezing, or sugar should be added after the second freezing and centrifuging of unsweetened juice to increase the concentration to about 50° Balling. The added sugar reduces the tendency of the juices to oxidize and change in flavor.

Strawberry syrup is usually deficient in color, but the addition of a small proportion (10 to 20 per cent) of blackberry syrup produces a blend of rich strawberry flavor and of bright red color.

Berries do not yield palatable syrups without the addition of sugar although they have been concentrated by freezing and in vacuo successfully by the Seralian process, in which the volatile flavoring compounds are recovered and returned to the concentrated juice.

Pomegranate Syrup.—Pomegranate juice prepared as described in the chapter on fruit juices yields a syrup suitable for soda fountain and bottling use when sugar is added to increase the Balling degree to about 40°. This syrup blends well for beverage purposes with citrus juices. True Grenadine syrup should be made from pomegranate juice, but most so-called "Grenadine" syrup is a purely synthetic preparation.

Syrups from Dried Fruits.—Low-priced dried fruits of sound quality are sometimes used for the preparation of syrups for use in medicines or for table syrup. The fruit can be extracted with water in any one of several ways.

It can be soaked in water until plump (24 hours) and then crushed and pressed in the usual manner. The press cake should be soaked and pressed a second time.

The fruit may be heated in several changes of water and the dilute extract so obtained can be used to extract succeeding lots of fruit until an extract is obtained rich in sugar and requiring very little concentration by boiling.

The dry fruit may be crushed or shredded and extracted by percolation with hot water or by diffusion in a series of tanks arranged as in a sugar beet diffusion battery.

The sugary extracts prepared in any of the above ways must be further concentrated by boiling in the open or in vacuo or concentrated by some other suitable method. Because of their mild laxative action, syrups from dried prunes or figs are in use in certain pharmaceutical preparations.

Raisin syrup and syrup from other dried fruits are suitable for table and culinary purposes. The sugary extract from raisins can be neutralized with calcium carbonate, decolorized with vegetable carbon and concentrated in vacuo to give a water-white syrup.

Carefully dehydrated berries can be used for the preparation of syrups for soda fountain use and for bottling purposes.

SORGHUM SYRUP

Sorghum syrup is produced extensively throughout the Southwest and Middle Western states. The process of manufacture is simple and does not require expensive equipment. For this reason the syrup is more frequently produced on a small scale on individual farms than in large centrally located factories.

Wright gives the approximate annual production of the more important table syrups in the United States as follows:

	Gallons per Year
Sugar cane syrup	35–40,000,000
Corn syrup	30–35,000,000
Sorghum syrup	25–30,000,000
Molasses	25–30,000,000
Maple syrup	3– 5,000,000

Sorghum syrup is usually of heavy consistency varying from 70 to 80° Balling, the color is light brown to amber and the syrup possesses a pleasing flavor characteristic of the sorghum cane. Its principal use is as a table syrup, but it is also often used in cooking as a substitute for sugar.

Harvesting.—Sweet sorghum cane contains the maximum of sugar when the grain has reached the hard dough stage. The effect of maturity is shown by the results of analyses of 2,740 samples of sorghum by Collier and reported by Bryan.[1]

If cut too green the sap will be low in sugar and the syrup will be of poor flavor. If cut too ripe, the cane will be dry and the yield of sap low.

The leaves, suckers, seed heads and seed stems injure the flavor of the sap and are removed before the canes are crushed. In many cases this is done by hand in the field. A piece of wood sharpened on one edge is used to cut the leaves from the canes, the operation being known as "stripping." The heads and 6 to 12 inches of the seed stem are cut from the standing canes with a corn knife, although in some cases the stripped cane is cut with a binder and the heads are cut from the canes in the

bundle. The seed heads can be collected in piles and hauled to a drying yard or shed. The leaves are more difficult to recover, although if the cane is cut promptly after stripping it is possible to rake the leaves and utilize them for silage or for feeding in the fresh state to stock.

TABLE 46.—SUGAR CONTENT OF SORGHUM CANE AT VARIOUS STAGES OF GROWTH
(*After Bryan*)

Stage of cutting	Total sugar, per cent	Sucrose, per cent	Invert sugar, per cent
Panicles just appearing	6.05	1.76	4.29
Panicles entirely out	8.01	3.51	4.50
Flowers all out	9.28	5.13	4.15
Seed in milk stage	11.24	7.38	3.86
Seed in dough stage	12.14	8.95	3.19
Seed dry, easily split	13.01	10.66	2.35
Seed hard dry	13.50	11.69	1.81

Machinery is available for removing the leaves and seed heads from sorghum cane which has been harvested without previous stripping of leaves and harvesting of seed heads in the field. Where such equipment is used the harvesting can be done by machinery.

It is usually desirable to crush the cane as soon as possible after harvesting in order to avoid deterioration through "heating" and fermentation. Frozen cane quickly develops fermentation on thawing.

Extraction of the Juice.—Sorghum cane contains 70 to 80 per cent of water. It is possible to obtain with thorough pressing a yield of juice equal to from 50 to 60 per cent of the weight of the cane.

The juice is extracted by passing the cane between the iron rolls of a cane mill. The simplest mill consists of two vertical rolls operated by a sweep and horsepower, the distance beween the rolls being adjusted to suit the size of cane and the rate of feeding. The three-roll mill is more powerful than the two-roll mill and gives a higher yield of juice. The cane first passes between two of the rolls set at a medium distance apart and then between the second and third rolls, which are set very closely together and exert a very heavy pressure.

Clearing the Juice.—The undissolved impurities may be removed to a large extent by settling of the freshly pressed sap in tanks or barrels of suitable size. Long shallow tanks with baffles to retain sediment or floating materials are sometimes used for the continuous settling of the sap.

The juice is rich in heat-coagulable compounds which aid in the clarification, when the fresh juice is heated. The normal procedure is to skim

the juice and syrup by hand during the boiling process and thus remove both the coagulated proteins and sediment occluded by the coagulated material.

In large syrup establishments the sap may be heated to boiling and then filtered through filter press or pulp filter, a method which is less wasteful than the skimming method.

The sap may be clarified by boiling and settling with a suitable quality of clay in much the same manner as described in Chapter XV for the fining of fruit juices with Spanish clay. Fireclay is not suitable.

Fig. 60.—Large "clam shell" filter press suitable for the filtration of sorghum, cane and other juices or syrups. (*Courtesy of the United Filters Corporation*).

Concentrating.—The usual equipment for concentrating sorghum sap to syrup is the sorghum pan and furnace described earlier in this chapter. The juice enters one end of the pan, follows a zigzag path through the pan and emerges at the opposite end as syrup. During its passage it boils vigorously and is skimmed to remove coagulated material and floating particles of pulp.

In some large factories the sap is concentrated in vacuum pans which produce a syrup of lighter color and with less caramelized flavor than is obtained in the open pan.

The syrup must be concentrated to at least 70° Balling (or Brix) cold test in order to prevent spoilage by fermentation or molding, but when concentrated too far, crystallization of cane sugar (sucrose) will occur. Crystallization is more apt to occur in syrup made from juice neutralized with calcium carbonate or hydroxide than in syrup made

from juice not deacidified, because considerable inversion of the sucrose to dextrose and levulose occurs in the boiling of acid juice.

The end point can be determined by a Balling saccharometer, making the necessary correction for temperature, or by observing the boiling point. A syrup of 70° Bolling boils at about 13°F. above the boiling point of water.

Deacidification.—Occasionally, in order to modify the flavor and to clarify the sap, slaked lime is mixed with water and added to the sap, or powdered calcium carbonate is added direct. Neutralization is conducted at the boiling point and the end point is determined by the use of litmus paper. It is doubtful whether the addition of lime or calcium carbonate results in the precipitation of more organic matter than occurs with boiling without such addition.

Treatment of the Syrup.—The finished syrup should be promptly cooled to avoid darkening of the color by prolonged heating. This can be done by allowing the syrup to flow through a coil immersed in cold water or in fresh juice; if in the latter, the heat of the syrup is utilized in preheating the sap.

Settling of the syrup or filtration through felt, sand or other permeable filter is desirable. Some manufacturers filter the partially concentrated juice and thus avoid the necessity of settling or filtering the finished syrup.

The clear syrup is marketed in barrels or kegs or cans.

Yields.—Under California conditions the average yield of unstripped cane is about 14 tons per acre, equivalent to about 12 tons of stripped cane, or about 130 gallons of syrup, per acre. On unirrigated land the yield is less and on rich, well-watered soil more than this. In most districts 100 gallons of syrup per acre is considered a satisfactory yield.

MAPLE SYRUP

At one time maple syrup and sugar were staple food products and their manufacture a very important industry. They are now considered delicacies and the amount of true maple syrup and sugar is relatively so small, compared to the imitation maple, that it has been stated that the amount of "maple" syrup on the market would not decrease appreciably if none of the maple sugar trees in America were used for syrup production. Nevertheless, the maple syrup industry is still an important one.

Districts.—New England, New York, Pennsylvania, the Ohio Valley, the Lake states and adjacent parts of Canada are the principal regions in which the sugar maple (*Acer saccharum*) is found in abundance and are the principal maple syrup producing regions. In the Southern States the sugar maples occur but do not appear to produce a sap suitable for syrup making.

Tapping.—The opening and closing dates of the maple sap season vary considerably from year to year according to the opening of spring and

according to the locality. It may start as early as the fifteenth of February or as late as the middle of April in a given locality. "Sugar weather" is a term well known to the syrup manufacturers and may be described as weather in which the temperature during the day rises above 32°F. and drops below the freezing point at night. If the season starts with bright sunny days the flow of sap will be very rapid and the season short. High winds check the flow of sap and unusually warm weather or a heavy freeze often stops it.

Holes.—To obtain the sap one or more holes are bored in the tree and buckets are attached to spouts inserted in the holes. It is considered that more than one hole per tree shortens its life, and except in very large trees one hole will suffice. The hole should be located at a place where the bark and wood are healthy and vigorous in order to reduce liability of infection and decay. The hole is ordinarily located at a convenient height for the workman, usually about waist-high. The size of the hole should be such that it will heal over completely in one season, a hole $\frac{3}{8}$ to $\frac{1}{2}$ inch in diameter usually being considered best. A small hole may be reamed out to obtain a second flow of sap should weather conditions become favorable. The hole is bored with a slight upward slant to favor flow of sap from the hole and to reduce the tendency for the sap to ferment or sour. A sharp clean cutting bit should be used to avoid "feathering" of the wood in the hole, with consequent souring of the sap in the roughened surface. The hole should pass through the sapwood only and should not penetrate the heartwood. Most trees will require a hole not more than 2 inches deep.

Spouts.—A spout or spile is inserted in the opening for collection of the sap. The best forms of spouts are perfectly cylindrical, smooth and of even taper. This form may be easily inserted and removed without injury to the wood tissue. Spouts which are liable to split the bark or crush the sapwood should be avoided. The weight of the bucket should rest upon the bark and not upon the sapwood.

Buckets.—Metal buckets are to be preferred to wooden buckets for the collection of the sap, since they are lighter, more easily cleaned and not so liable to become foul through fermentation and souring of the sap during warm weather. Heavily tinned buckets are more satisfactory than galvanized buckets because the zinc coating of the latter is fairly soluble in the sap. Buckets of slender rather than flaring design can be most conveniently hung to the trees.

Buckets should be covered in order to exclude rain, snow, insects, etc., and to reduce darkening of the sap by sunlight. Tapping buckets vary from 8 to 15 quarts in size.

The sap is gathered periodically in larger buckets and is poured into a hauling tank, usually mounted on a sled. Wooden tanks are more liable to become sour through fermentation of the sap in the wood pores

than are metal tanks, and if used should be painted on the inside. The sap is transported to the boiling house by means of the hauling tank.

Concentrating the Sap.—The sap contains from 1 to 5 per cent total dissolved solids, principally sucrose. During freezing weather the sap in the buckets will freeze at night and if not completely frozen the ice may be separated from the remaining sap and discarded; thus effecting a considerable concentration of the sap.

Concentrators.—At the boiling house the sap is concentrated as described elsewhere for sorghum sap, the sorghum pan being commonly used for this purpose. Iron kettles are frequently used by small producers and steam-heated pans by the larger factories. Wood is the usual fuel.

Iron kettles are objectionable principally because the sap is subjected to a prolonged period of boiling and becomes darkened or scorched in flavor. Boiling should be completed rapidly if a syrup of light color and good flavor is desired.

Skimming.—During boiling, proteins are coagulated and come to the surface and this coagulum is removed by skimming during the boiling operation. White of egg or other clarifying agents are sometimes added, but are liable to alter the flavor of the finished product. The addition of baking soda to cause the coagulated matter to rise to the surface is objectionable, because it may so greatly reduce the acidity of the sap that the flavor is injured.

A separation of mineral salts, principally calcium malate, occurs during the boiling of the sap and these are usually removed by settling of the syrup after boiling is completed.

Balling Degree.—Maple syrup is concentrated to about 65° Balling. If it is less than 65° Balling it will ferment and if above 70° Balling it is very apt to crystallize, owing to the separation of sucrose. Syrup of 65° Balling weighs 11 pounds per gallon at 60°F.

Canning.—Most maple syrup is sold in cans of quart, half gallon or gallon size.

CANE SYRUP

Syrup is produced in the Southern States in commercial quantities from sugar cane by methods very similar to those discussed for sorghum syrup

Culture.—A number of varieties of cane are used for the purpose but all of these belong to the species *Saccharum officinarum.* To be suited to profitable growth in the Southern States, the cane must be a quick-maturing variety, two of the best known varieties being the Louisiana Purple and the Louisiana Striped.

Harvesting.—Harvesting may begin in October, but more generally in November, and is accomplished by hand by much the same methods

as used for sorghum cane. The leaves are first stripped from the cane and the cane is then cut by hand with a heavy knife.

Composition of Cane.—The composition of the cane varies with the season and other conditions, but normally 88 to 90 per cent of its weight is juice. By use of modern mills with 9 to 12 rollers it is possible to extract 80 to 85 per cent of the weight of the cane and with small mills less, even as low as 55 per cent.

The juice from cane produced in the Southern States contains about 11 to 14 per cent of sucrose, 1.5 to 2 per cent invert sugar and about 1.3 to 2 per cent of solids other than sugar.

Yields and Costs.—Yoder[5] estimates the cost of producing the first year's crop of cane at $54 per acre, or equal to a cost of $2.45 per ton of cane, $3.60 per barrel of syrup or 11 cents per gallon of syrup, if the yield is 22 tons of cane per acre. He estimates the cost of manufacturing the syrup from the cane (in 1917) to be approximately 11 cents per gallon in small plants and 10 cents per gallon on a factory scale. Growing the cane and making the syrup, therefore, cost not less than 21 cents per gallon of syrup produced. The average cost at present is considerably in excess of this figure.

Making Syrup.—Dale[20] states that two general methods of making cane syrup are in use. In one of these the cane is crushed in large sugar cane mills; the resulting juice is clarified by treating with sulphurous acid, lime, settling and filtering, and the clear juice is concentrated in steam-heated open pans or vacuum pans. The syrup is light in color and of fairly uniform quality. In the second method the cane is pressed in small mills on individual farms and is concentrated in direct-fired sorghum pans. The resulting product is not uniform in quality and much of it is inferior.

Dale and Hudson[19] recommend filtration of the raw juice through a filter press after boiling with infusorial earth (10 pounds to the juice from 1 ton of cane) and concentration in vacuo. This yields a syrup superior in appearance and flavor to that obtained by other methods.

SYRUP FROM SWEET POTATOES

Oversize, blemished and misshapen sweet potatoes, according to Gore,[6] often represent 40 per cent or more of the total crop and are usually allowed to go to waste. He has developed a relatively simple process for converting them into a palatable table syrup.

Blanching.—The sorted and trimmed potatoes are boiled in three changes of water to remove soluble materials from the skins which would otherwise injure the flavor and color of the syrup.

Cooking.—The blanched potatoes are then boiled in water or steamed until soft in order to gelatinize the starch and prepare it for mashing.

Water equal to about twice the weight of the potatoes is then added and the potatoes stirred until thoroughly broken up and mixed with the water.

Mashing.—The temperature of the mixture is then brought to 140°F. and about 1 per cent of finely ground pale barley malt free from sprouts is added and thoroughly mixed with the potatoes. The "mash" is held at 125 to 145°F. (preferably 140°F.) until a drop of filtrate from the mash fails to give a blue coloration when mixed with dilute iodine solution. The mashing period is 20 minutes to 1 hour.

The diastase of the barley malt during the mashing process converts the starch of the potatoes into maltose, according to the following reaction:

$$\underset{\text{starch}}{(C_6H_{10}O_5)x} + H_2O + \text{diastase} = \underset{\text{maltose}}{xC_{12}H_{22}O_{11}}$$

Dextrins are obtained as intermediate products and the saccharified mash contains a small amount of dextrine.

Pressing.—The wort (sweet liquor) is separated from the pomace by pressing in a rack and cloth fruit press.

Clearing the Wort.—The wort may be boiled and filtered in a filter press with infusorial earth.

Concentration.—The juice may be concentrated in any one of the syrup-concentrating devices described earlier in this chapter.

Refining.—Frequently the syrup possesses an "off flavor." In such cases the partially concentrated syrup should be mixed with a small amount of bone black or vegetable filter char and about 3 per cent of its weight of infusorial earth, boiled a short time and filtered. A syrup of neutral flavor may then be prepared by concentrating the refined syrup to the desired density.

Yield.—The yield of syrup is equal to about one-third the weight of the raw potatoes used.

Character of the Syrup.—If properly prepared the syrup is of light amber color and of mild but characteristic flavor.

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CHAPTER XVII

JELLIES AND MARMALADES

The manufacture of jellies and marmalades is one of the oldest and most important of the fruit products industries, and affords a means of utilizing a large amount of sound cull fruit unsuited to other purposes.

DEFINITIONS

Jelly.—Jelly is prepared by boiling fruit with or without water, expressing and straining the juice, adding sugar (sucrose) and concentrating to such consistency that gelatinization takes place on cooling. A perfect jelly is clear, sparkling, transparent and of attractive color. When removed from the glass it should retain its form and should quiver, not flow. It should not be syrupy, sticky or gummy and should retain the flavor and aroma of the original fruit. When cut it should be tender and yet so firm that a sharp edge and smooth, sparkling cut surface remain.

Marmalade.—A true fruit marmalade is a clear jelly in which are suspended slices of fruit or peel. Frequently jams are mislabeled as marmalades.

CONSTITUENTS OF JELLY

Three substances are essential to the preparation of a fruit jelly. These are pectin, acid and sugar. Of these pectin is the most important.

Pectin.—It is possible to make a jelly of excellent consistency by combining pectin, acid, sugar and distilled water in the proper proportions. Fruit juices which are normally deficient in pectin or acid, or both, will make good jelly if these constituents are added. More will be said of pectin later in this chapter.

Acid.—Acid is a necessary constituent of fruit jellies. Juices that are deficient in acidity will make good jelly if citric, tartaric or other suitable acid is added, provided the proper proportions of pectin and sugar are present. The effect of various concentrations of acid on the jelling point will be discussed later.

Nature of Jelly.—It is probable that the formation of fruit jelly from pectin, sugar and acid is not a stable chemical compound, because if fruit jelly is diluted with warm water the constituents of the jelly go into solution and may be recovered by suitable means. Attempts have failed to obtain the sugar-pectin-acid compound that has been assumed to exist by some.

According to Bigelow,[3] Fremy thought that the formation of jelly is due to the jelling of pectic acid formed during the boiling process, but this theory has been disproved.

Soule[12] states that some fruit juices may fail to give a jelly even if sufficient pectin is present, because of the inhibiting effect of certain colloids. However, he gives no specific data to prove this hypothesis. By means of an ultramicroscope he states that it is possible to demonstrate the presence of a network in starch jellies, and that this network is probably responsible for the jelly-like consistency. He was unable to observe such a network in pectin jellies, although many chemists believe that such a network exists.

Sugar.—Sugar, the third necessary constituent of fruit jellies, may be in the form of any of the readily soluble sugars, such as cane sugar (sucrose), dextrose, levulose, maltose, etc. Jelly forms when the concentration (specific gravity) of the solution of sugar, acid and pectin equals or exceeds a certain minimum which varies according to the relative proportions of pectin and acid present. Singh[18] obtained jelly at a concentration of 50 per cent cane sugar when the acidity was 3.05 per cent (as citric) and the pectin concentration was 1.5 per cent. At 0.3 per cent acid and 1.5 per cent pectin, jelly did not form until the sugar concentration reached 61.5 per cent. See Fig. 63 for curves showing relation of pectin and acid concentration to jelling point.

PECTIN AND RELATED COMPOUNDS

Since pectin is so important in the preparation of jellies and marmalades, it is desirable that at least a brief discussion of this and related compounds be given.

Pectose or Protopectin.—Pectose or protopectin is the "mother substance" from which pectin is derived. It has also been given the name of "pectocellulose." According to Caldwell,[10] pectose is found in the middle lamellae of the cell walls of fruits and plants and is located between layers of cellulose. It has been thought by certain investigators that the pectic substances in the cell walls exist there as salts of calcium; but von Fellenberg[9] has demonstrated that most of the pectin bodies exist in the fruit as pectose, pectin or pectic acid, and not as salts of calcium. Pectose is closely related to lignin and cellulose.

Pectose is most abundant in fruit during the hard green stage and as the fruit ripens it is converted into pectin by the action of an enzyme. When the fruit has passed the stage of full maturity and has undergone decomposition by microorganisms or by enzymes, pectin is converted into pectic acid and methyl alcohol. As the pectose changes to pectin during ripening, the texture of the fruit softens, probably not only through the weakening of the cell walls because of the conversion of the pectose (an

insoluble solid) to pectin (a soluble compound), but also because of the actual separation of the individual cells from each other, owing to the swelling of the pectin through the absorption of water.

Haas and Hill[8] classify the pectic bodies in relation to other carbohydrates as follows:

Monosaccharides..........	Pentoses ($C_5H_{10}O_5$) arabinose, xylose, rhamnose, etc. Hexoses ($C_6H_{12}O_6$) dextrose, levulose, mannose, galactose, etc.
Dissacharides............	($C_{12}H_{22}O_{11}$) sucrose, maltose, lactose, etc.
Polysaccharides...........	Starches ($C_6H_{10}O_5$) starch, dextrine, inulin, glycogen, galactosans, including galactan and paragalactan. Gums ($C_5H_8O_4$) (*a*) arabin, cerosin, pentosans. (*b*) mucilages, pectic bodies. Celluloses ($C_6H_{10}O_5$)

Gums when hydrolyzed yield galactose and pentoses, such as xylose and arabinose. Pectose when hydrolyzed yields pectin, and if the hydrolysis is continued, pectic acid and methyl alcohol. Bigelow suggests that pectic bodies may exist in combination with cellulose in the form of pectocelluloses and that the pectic bodies may be separated from the cellulose portion of the combination by boiling. It is a well-recognized fact that juice pressed from apples without previous heating of the fruit contains only a small amount of pectin, whereas juice expressed after boiling of the apples is rich in pectin. This condition may be due to hydrolysis either of pectose or of pectocellulose. In any event it is probable that the pectose and cellulose are rather closely associated.

Composition of Pectin.—In defining pectin we refer to those bodies in fruit juices which go into colloidal solution in water and are derived from pectose (protopectin) by ripening processes or other form of hydrolysis. Under certain conditions in the presence of the proper proportions of sugar and acid they will form jelly.

Preparation.—According to Von Fellenberg[9] one of the best methods of preparing pure pectin for laboratory study is that of Bourquellot and Herissy, in which fruit rich in pectin is boiled repeatedly under a reflux condenser with ethyl alcohol until sugars and other substances soluble in alcohol are extracted. Boiling with alcohol also results in hydrolysis of most of the pectose to pectin. The alcohol-extracted pulp is boiled with water, pressed and the liquid so obtained filtered and treated with twice its volume of alcohol to precipitate the pectin, which can be redissolved in water and reprecipitated with alcohol and dried.

Analysis.—Von Fellenberg[9] has found that pectins from different fruits vary considerably in composition, but that they are made up of the same basic groupings: pentoses, methyl pentoses, carboxyl radicles, methoxyl groups and mucic acid forming groups. In the analysis of orange pectin Von Fellenberg obtained the following results:

Arabinose	41.0% equivalent to	36.1% araban
Methyl pentose	6.7% equivalent to	6.1% methyl pentosan
Galactose	54.8% equivalent to	49.3% galactan
Methyl alcohol	11.5% equivalent to	11.5% methyl alcohol
Total		102.9%

He explains his high results for total composition to overestimation of the galactose which was computed in terms of mucic acid.

Apple pectin gave approximately 10.54 per cent methyl alcohol and 15.73 per cent arabinose. Swedish turnips yielded pectin containing 8.9 per cent methyl alcohol, currant pectin 9.3 per cent and quince pectin 10.26 per cent of methyl alcohol.

Methyl alcohol is liberated quantitatively by hydrolysis of the pectin with dilute alkalies, even without heating, and can be estimated by Denige's or Zeizel's methods.

The nature of the methyl pentose grouping is not definitely understood. Tollens believes that there is present in the pectin molecule an esterified carboxyl group, COOH, in place of the CHO or CH_2OH group of the carbohydrate. Thus, pectin would be a methyl ester of pectic acid and hydrolysis of pectin with dilute alkali would be in the nature of saponification. The work of Von Fellenberg has definitely disproved the older conception that pectin, pectose and pectic acid are isomers or polymers.

A wide range of combinations of the constituents of pectin is possible and it is reasonable to assume that there are a number of different pectins in nature, since pectin from different fruits and vegetables varies considerably not only in its content of CH_3OH, but also in its physical properties and behavior when used for jellies.

Physical Properties of Pectin.—Pectin is a reversible colloid; that is, it may be dissolved in water, precipitated, dried and redissolved without alteration of its physical properties.

On the addition of water to dry pectin, paste-like lumps are first formed. These finally go into solution but solution is greatly hastened by heating the mixture and by adding sugar. A solution clear by transmitted but cloudy by reflected light is obtained.

Under the ultramicroscope there will be found in this solution numerous particles in lively motion. These particles vary in size, but are (ultramicroscopically considered) small.

In addition to alcohol, several metallic salts have the power of precipitating pectin and at one time it was considered that the precipitates of pectin with metallic salts were definite chemical compounds. Analyses of the precipitates give varying ratios of salt to pectin and the present conception of the precipitation is that it is an electrolytic coagulation similar to that which occurs with many other colloids when suitable electrolytes are added.

Effect of Enzymes.—Enzymes, present in fruits in insoluble form and in certain roots in soluble form, have the property of hydrolyzing pectin to pectic acid and alcohol. An enzyme capable of bringing about this reaction is known as pectinase.

Methyl alcohol may be demonstrated in apples that are covered with paraffin and allowed to stand at 35°C. for a few days and the same is true of apples placed in water containing toluene. Fruit which has become over-ripe and begun to decay also contains methyl alcohol. These facts confirm the presence of pectinase in fruits.

Pectic Acid.—Pectin yields on hydrolysis with dilute alkalies, pectic acid which can be precipitated from solutions in which hydrolysis has taken place, by the addition of a mineral acid.

Hydrolysis of apple pectin yields about 95.17 per cent pectic acid and of orange pectin about 94.8 per cent. During saponification the $COOCH_3$ grouping is changed to $COOH$, which causes an increase in weight, approximately equivalent to the difference in the methyl alcohol yield actually obtained and that found by subtracting the per cent of pectic acid obtained from 100.

Pectic acid is a white powder, if pure, fairly soluble in water and forms a clearer solution than does pectin. It will conduct an electric current and is sour in taste.

Precipitation of Pectic Acid.—Small amounts of electrolytes cause coagulation of pectic acid solutions.

Univalent cations are less active than divalent, and divalent in turn less active than trivalent cations. The differences in precipitation value of these salts are of the same order of magnitude as those for the precipitation of colloidal sulphides.

Pectic acid is precipitated quantitatively as calcium pectate and this fact is made use of in one method of analyzing pectin solutions.

The relation of pectic acid, pectin and pectose is shown by the following diagram:

Protopectin → Pectin (pectic acid) (methyl ester)
By ripening, boiling in water, alcohol and dilute acids

Protopectin → By sodium hydroxide, cold → Pectic acid and methyl alcohol

Pectin → Pectic acid and methyl alcohol
By pectinase, especially by rotting of fruit or by $NaOH$, $Ca(OH)_2$ and $Ba(OH)_2$

Preparation of Commercial Pectin.—Cull apples and waste peels and cores from canneries and evaporators have been used for many years as a source of juice, which is blended with other fruit juices in the commercial production of jellies. During the past 3 or 4 years there has been increased activity in the preparation of powdered pectin or pectin syrups for the use of jelly makers.

Alcohol Precipitation.—In 1913 P. R. Boyles[13] was granted a patent upon a process for the preparation of pectin by extraction of the pectin by boiling with water, concentration of the resulting solution by boiling and precipitation of the pectin from the concentrated solution by the addition of ethyl alcohol. The principal objection of the precipitation of pectin with alcohol is the difficulty of recovering all of the alcohol.

Extraction.—Waksman[18] states that in the preparation of a pectin concentrate from apples, the apple pulp (usually dried pomace) is diffused with cold water to extract most of the acid and sugar. The cold water does not dissolve any appreciable proportion of the pectin. The residue after water extraction is then boiled 35 to 40 minutes with water containing a small amount (about 0.1 per cent) of tartaric acid. The juice is pressed from the heated pulp and cooled.

Hydrolysis of Starch.—A small amount, 1½ to 3 ounces per 100 pounds of extract, of diastasic enzyme from a mold of the aspergillus group is added and the mixture is maintained at 45 to 50°C. (110 to 120°F.) to hydrolyze the starch in solution and thus prevent starch "haze" in jelly made from the pectin extract.

After hydrolysis the solution is filtered and is then concentrated in vacuo to a thick syrup, which is preserved by sterilization in bottles. Cans have also been used as containers for pectin concentrates, although there is danger of perforation of the tin plate.

Precipitation by Mineral Salts.—Magoon and Caldwell[15] have described a process in which pectin is precipitated by mineral salts. Apple or other fruit pulp is boiled with several changes of water. The combined extracts are treated with a small quantity of saturated commercial alum solution with constant stirring; ammonium hydroxide is then added in slight excess of neutrality and the solution is warmed to coagulate a voluminous precipitate which forms on addition of the alum and ammonia. The liquid is then filtered and magnesium sulphate in crystalline form is added at the boiling point, the additions and boiling being continued until a precipitate no longer forms. The precipitate of pectin is separated by filtration and is washed with cold water to remove occluded salts. The washed pectin can then be dried and will retain its jelling power indefinitely.

SUITABILITY OF VARIOUS FRUITS FOR JELLY

Fruits for jelly should contain sufficient acid and pectin to yield a good jelly without the addition of these substances. Some fruits contain enough of both pectin and acid for the purpose; others are deficient in one or the other of these constituents and others are deficient in both acid and pectin. They may be roughly classified on this basis.

Of the fruits rich in acid and pectin, crab apples, acid varieties of apples, loganberries, sour varieties of blackberries, currants, lemons,

limes, grapefruit, sour varieties of oranges, sour varieties of guavas, Damson plums, most other varieties of sour plums, Labrusca varieties of grapes, sour varieties of cherries, cranberries and roselle are good examples. Of fruits and vegetables low in acid but rich in pectin the following may be cited: sweet varieties of cherries, unripe figs, pie melon, carrots, unripe bananas and ripe quinces. Fruits and vegetables that are rich in acid but low in pectin are apricots, rhubarb and most varieties of strawberries. Fruits which may be classed as containing a moderate concentration of both acid and pectin are ripe Vinifera varieties of grapes, ripe blackberries, ripe apples, loquats and feijoas. Fruits low in both acid and pectin are represented by pomegranates (arals), ripe peaches, ripe apricots and Bartlett pears.

It is customary to blend fruits deficient in acid or pectin, or both, with fruits which have an abundance of the required constituents.

Because it possesses no appreciable flavor of its own, commercially prepared pectin is coming into more general use for the purpose of enriching juices of fruits deficient in this component.

THE PREPARATION OF JELLY

The process of jelly making may be discussed conveniently under several operations, namely: those of boiling the fruit, of extraction of the juice, clearing the juice, adding the sugar, boiling, packaging and sterilizing.

Boiling the Fruit.—Most fruits should be boiled for extraction of the juice in order to obtain the maximum yield of juice and pectin, because boiling converts pectose into pectin and softens the fruit tissue.

Very juicy fruits, such as berries, do not require the addition of water and need only be crushed and heated to the boiling point for 2 or 3 minutes. For most berries the shorter the period of boiling the better the flavor of the resulting jelly. Firm fruits, such as apples and oranges, are cut or crushed and require the addition of water. Citrus fruits are cut in pieces about 1/8 to 1/4 inch in thickness.

The length of boiling will vary according to the variety and texture of the fruit. Apples normally require only 20 minutes or less and oranges from 30 to 60 minutes. The fruit should be heated only long enough to soften it sufficiently to permit thorough extraction of the juice by pressing and not long enough to render it "mushy." Fruit which is boiled too long yields a cloudy juice which is very difficult to filter.

Amount of Added Water.—The amount of water that should be added to the fruit should be sufficient only to obtain a good yield of juice and pectin. Juicy fruits require no water; apples from one-half to an equal volume of water, and citrus fruits, because of the long period of boiling necessary, usually require from two to three volumes of water for each volume of sliced or crushed fruit. If too much water is used the

resulting juice will be too dilute and will require an undue amount of concentrating before jelly can be made from it; if too little water is used there is danger of scorching the fruit or of obtaining a low yield of juice and jelly. Fruits very rich in pectin, such as currants, loganberries, cranberries, lemons and Labrusca (eastern) varieties of grapes, can be extracted to advantage with two or more succeeding lots of water.

Fig. 61.—Tilting jelly kettles. (*In Fruit Products Laboratory, University of California, Berkeley, Cal.*)

Kettles.—The extraction of juice from fruits for the preparation of jelly on a commercial scale is usually accomplished by the use of steam-jacketed copper kettles, placed on a platform or a floor above the press so that the cooked pulp and juice may be drawn from the kettle by gravity to the press. If a large kettle (50 or more gallons' capacity) is used it should be fitted with a large valve (2 inches or larger) to permit drawing off of the fruit. If the installation is of small size a tilting kettle is most convenient.

Effect of Various Metals.—Copper injures the color of fruits if contact at the boiling point is prolonged and aluminum is for this reason to be preferred for most fruits. Glass-lined equipment is least liable to cause injury to the color of fruits and should be used for the boiling of citrus and other fruits which may require a long period of boiling. Silver plated steam coils can be used in steam-jacketed, glass-lined kettles to increase the rate of heating. The principal objection to steam-jacketed, glass-lined equipment is its slow conductance of heat, because of the thickness of the walls.

Pressing.—The housewife, in preparing juice for jelly making, does not usually press the fruit; she merely places the heated pulp and juice in a cloth jelly bag and allows it to drain, in order to obtain a clear juice.

In the jelly factory a high yield of jelly juice rich in pectin and obtained with a minimum of handling is desired. The use of the rack and cloth press has been found in practice to be one of the most desirable means of pressing the juice from the boiled pulp. The hot fruit and juice direct from the kettle are placed in the cloths of the press and pressed as described in Chapter XV on fruit juices.

Use of Pomace.—The press cake may, if desired, be mixed with water in the kettle and heated a second time to obtain the remaining pectin. This is probably not advisable for cheap fruits, such as apple culls and apple waste or citrus fruit culls, but may become profitable with more costly fruits, such as currants, loganberries, etc.

The press cake (pomace) has some value as stock food and can be fed direct, or it can be dried, stored and used as needed. It has very little fertilizing value, but can be used to improve the texture of heavy soils if mixed with lime in order to prevent formation of harmful concentrations of acid in the soil.

Clearing the Juice.—Jelly is most attractive when clear and most jelly factories now use mechanical filters.

Filtration.—In the Fruit Products Factory at the University of California a small pulp filter is used successfully, as described in Chapter XV. Filtration is rapid and the filtered juice is fairly clear, and second filtration renders the juice brilliantly clear. This same type of filter is utilized upon a large scale in many commercial jelly factories.

Filter presses can also be used, but these usually become clogged quickly, unless the juice is mixed with infusorial earth. If from 1 to 3 per cent of a good grade of the earth is mixed with the juice, filtration is fairly satisfactory. The earth forms a filtering layer on the press cloths and thereby reduces sliming or clogging.

For the small jelly factory, heavy felt jelly bags can be used to improve the clearness of the juice, although it is usually not possible to obtain a brilliantly clear jelly by their use.

Filtration must be accomplished before the addition of sugar, because the latter so increases the viscosity of the juice that filtration becomes extremely slow or impossible. If the juice requires concentration by boiling before the addition of sugar, this should be done before filtering, since boiling causes precipitation of organic matter (probably protein), which should be removed by filtration or other means before sugar is added.

Settling.—Some fruit juices can be satisfactorily cleared by settling overnight in vessels 1 to 3 feet in depth. Shallow tanks should be used because of the relatively slow rate of settling of juices from boiled fruits.

Finings.—Numerous experiments have been made (Cruess and McNair[5]) upon the clearing of jelly juices by the use of finings, but none of the ordinary finings were very satisfactory.

Centrifuging.—Recently, experiments with centrifugal clarifiers have proved that jelly juices can be satisfactorily clarified by centrifuging at a high speed, both the Sharpless and De Laval clarifiers being used successfully for the purpose. As much of the coarse pulp as possible should be removed before centrifugal clarification, in order to avoid too rapid clogging of the bowl of the clarifier. This method is rapid and inexpensive in operation and deserves more serious study and attention from jelly manufacturers.

Addition of Sugar.—The housewife usually guesses at the amount of sugar that her jelly juice will require, and to juices that she believes rich in pectin she adds an equal or greater volume of sugar, and to juices that she has found by experience to be of poor quality for jelly, less than an equal volume of sugar. Many jelly makers proceed on this same basis.

Pectin Test.—A simple and very useful test to determine the proper proportion of sugar to use is the pectin-and-alcohol test, in which a spoonful of the juice and a spoonful of 95 per cent grain alcohol (denatured alcohol will serve the purpose) are mixed in a tumbler. A juice rich in pectin forms a jelly-like mass, one of medium pectin content several large lumps of jelly-like material and one poor in pectin forms a few small pieces of stringy precipitate or no precipitate whatsoever. From the results of this test one can intelligently judge the amount of sugar that may be added to the juice. Thus to a juice containing a large amount of pectin may be added at least 1 cup of sugar per cup of juice; to that of medium pectin content usually ½ to ⅔ of a cup of sugar per cup of juice, while the juice containing a small amount of pectin must usually be concentrated by boiling until it will give a satisfactory pectin test. The principal cause of failure in jelly making is the addition of too much sugar. Too large an addition of sugar so dilutes the pectin that jelly will not form. Therefore, the lower the pectin content of the juice the smaller the proportion of sugar should be.

The test must be standardized by experiment against factory practice, since the test at best is only relative, and when so standardized it becomes a valuable means of factory control.

Acid Determination.—The acidity of the juice is nearly as important as its pectin content. Titration of a 10-cubic-centimeter sample of the juice with N/10 sodium hydroxide, using phenolphthalein indicator, is a satisfactory means of determining the acidity. It is generally necessary to dilute the sample with about 100 cubic centimeters of distilled water, in order to make observation of the end point accurately. The acidity of the juice should be such that the finished jelly will contain at least 0.5 per cent total acidity, but preferably 0.75 to 1 per cent. Juices of low

acidity can be made into jelly without increasing the acidity, but an excessive amount of sugar or boiling will be necessary. It is usually more economical to increase the acidity of such juices by the addition of citric or tartaric acids or by the addition of a juice of high acidity.

The sugar should be weighed carefully and the volume of the juice accurately measured. If the volume of the kettle is known, it can be filled to a given height and actual measurement of the juice avoided. Measurement of the sugar by weight rather than by volume is desirable because of the greater accuracy of the former method.

FIG. 62.—Jelly thermometer for use in large jelly kettles.

It is not necessary to heat the sugar before it is added. It must be stirred with the juice in the kettle to avoid sticking and burning.

Boiling.—Boiling is one of the most important steps in the jelly making process, as it dissolves the sugar and causes union of the sugar, acid and pectin to form jelly. It usually causes a coagulation of certain organic compounds which can be skimmed from the surface during boiling, and their removal renders the jelly clearer. Its principal purpose is to increase the concentration of the sugar to the point where jelling will occur.

The boiling operation, while normally a necessary step in jelly making, should be as short as possible. Prolonged boiling results in loss of flavor, injury to color and hydrolysis of the pectin, and is a frequent cause of jelly failure.

Kettles.—Boiling in commercial practice is usually conducted in open steam-jacketed, copper kettles which may or may not be lined with tin or silver. Large kettles are less desirable than small ones, for the reason that the boiling process must be unduly prolonged in the larger vessels with consequent injury to flavor and color. Therefore, 25- and 10-gallon kettles are to be preferred to 50- or 110-gallon kettles. Boiling the juice in small lots permits more rapid boiling without danger of loss by frothing than is the case when the kettle is filled to capacity.

Skimming.—During boiling the juice should be skimmed if necessary in order to remove coagulated material and should be stirred to cause thorough mixing.

End Point.—The boiling is continued until on cooling the product will form a jelly of the desired consistency. The concentration of the mixture when this point is reached will depend upon several factors, namely, the concentration of pectin, the concentration of acid, the ratio

of sugar to pectin and acid and the texture desired. If the jelly is to be shipped long distances and subjected to rough handling, it must be stiffer than if it is to be stored on the pantry shelf at once or to be delivered to local dealers. In general, the finished product should be of the consistency described in the definition of jelly at the beginning of this chapter.

The most common method of determining the end point is by allowing the liquid to sheet from a wooden paddle or from a large cook spoon. If it drips from the instrument as a thin syrup the process is not complete; if it partly congeals and breaks from the paddle or spoon in sheets or forms jelly-like sheets on the side of the paddle or spoon the boiling is considered to be complete. The sheeting test is, however, subject to error because of the personal equation and because of variation in behavior of different lots of juice.

A more accurate method of determining the jelling point is by the use of a thermometer inserted in the boiling juice. If the juice contains the proper proportions of sugar, acid and pectin, the boiling point of the liquid at the jelling point will normally be about 8 to 9°F. above the boiling point of water. At sea level this will be at 220 to 221°F. and corresponds to a concentration of 65 to 70 per cent total solids in the jelly after cooling. It is also possible to use a hydrometer test on the hot liquid in order to judge the end point. A Balling or Brix hydrometer is suitable for the purpose but if the test is made on the juice near the boiling point the Balling or Brix degree should be approximately 58 to 60°, corresponding to about 65 to 67° Brix or Balling at room temperature. The thermometer and hydrometer tests should be confirmed by the sheeting test, since the juice may be so poor in pectin or acid that jelling will not occur until a greater concentration is reached that that given above, or so rich in these constituents that the jelling point is reached before a concentration of 65° Balling is reached.

If the jelly is to be preserved by pasteurization, the final concentration need not be as great as when the product is preserved by a high concentration of sugar. The housewife usually relies upon high sugar concentration to preserve her jelly, while the commercial manufacturer usually pasteurizes his product in hermetically sealed containers.

Flavor Changes.—Experiments (Cruess and McNair[5]) indicate that the changes in flavor that take place during the boiling of jelly are brought about both by loss of flavor through evaporation, by hydrolysis or other form of decomposition.

Hydrolysis of Sugar and Pectin.—Boiling of the sugar solution in the presence of the fruit acid results in inversion of some of the cane sugar to dextrose and levulose. For this reason a jelly which is boiled for a long period is less liable to develop crystals of sucrose (cane sugar) than is a jelly boiled a short time, assuming that the jelly in both cases is concentrated to the same point.

Pectin is also hydrolyzed by unduly prolonged boiling and the liquid may fail to jell under such a condition.

Relation of Pectin and Acid to Jelling Point.—It was stated above that the end point of the boiling process depends upon the concentration of acid and pectin present in the original juice. Recently Lal Singh,[18] working in the writer's laboratory, has studied quantitatively the relation of acidity to the jelling point of citrus fruit juice.

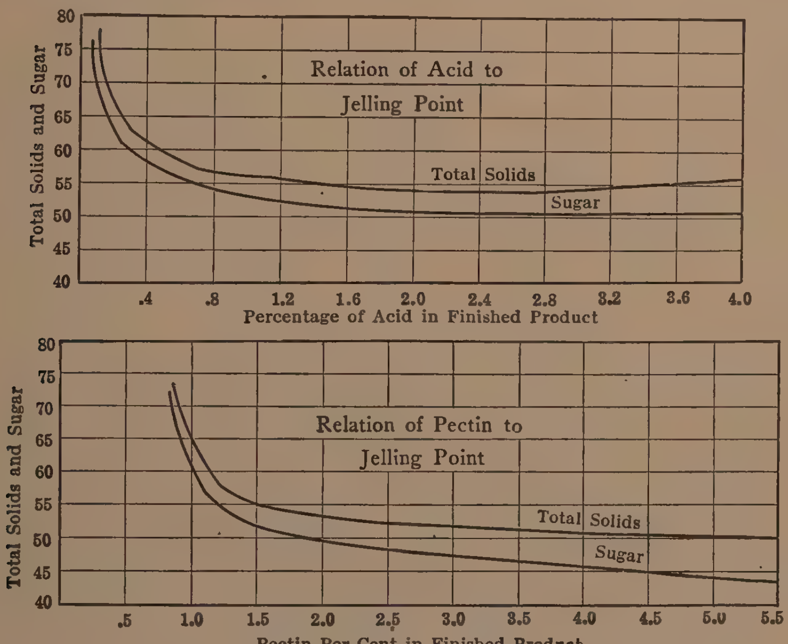

FIG. 63.—Relation of acidity and pectin to jelling point.

He used dried pectin from oranges, prepared by Bourquellot and Herissy's method, citric acid crystals, distilled water and cane sugar. A constant amount of pectin, 1.5 grams, was used in each test. The acidity was varied from 0.12 to 4.05 per cent, based on the finished product, and the proportion of sugar was also varied. An excess of water was used to dissolve the pectin, sugar and acid. The mixture was then concentrated by boiling to exactly 100 grams. The various samples were sealed in jelly glasses, stored and later examined to determine the sugar concentration at which jelly barely formed with a given acidity. The results are given in Table 47 and Fig. 63.

It will be noted that at 0.12 per cent acidity (as citric) 75 grams of sugar per 100 grams of jelly were necessary to form jelly; while at 1.05 per cent acidity jelly formed when the finished product contained only

53½ grams of sugar per 100 grams of jelly. These experiments prove that a material saving in sugar can be accomplished by increasing the acidity of juices deficient in acid.

TABLE 47.—RELATION OF ACIDITY TO SUGAR CONCENTRATION AT THE JELLING POINT
(*After Lal Singh*)

Lot No.	Amount of acid added	Per cent total acid	Sugar necessary barely to jell, grams	Total weight of jelly, grams
1	None	0.05	75	100
2	0.12	0.17	64	100
3	0.25	0.30	61½	100
4	0.50	0.55	56½	100
5	0.70	0.75	56½	100
6	1.00	1.05	53½	100
7	1.25	1.30	53½	100
8	1.50	1.55	52	100
9	1.70	1.75	52	100
10	2.00	2.05	50½	100
11	2.50	2.55	50½	100
12	3.00	3.05	50	100
13	3.50	3.55	50	100
14	4.00	4.05	50	100

Similar experiments were made to determine the effect of pectin on the jelling point. The data are summarized in Table 48 and Fig. 63.

TABLE 48.—THE EFFECT OF PECTIN CONCENTRATION ON THE SUGAR CONCENTRATION AT THE JELLING POINT
(*After Lal Singh*)

Percentage of pectin in finished product	Percentage of sugar present in finished product at lowest sugar concentration for jelling
0.50	No jelly formed at any concentration.
0.75	No jelly formed at any concentration.
0.90	65.0
1.00	62.0
1.25	54.0
1.50	52.0
1.75	51.0
2.00	49.5
2.75	48.0
4.20	45.0
5.50	43.0

In general the results resemble those obtained with variation of the acidity. No jelly was obtained at 0.75 per cent pectin, although other investigators have obtained jelly with less than this concentration of lemon pectin; a fact which might indicate that lemon pectin possesses greater jelling power than the pectin used by Lal Singh or that the latter's pectin was not free from impurities.

Relation of Hydrogen Ion Concentration.—Recently, L. W. Tarr of the Delaware Experiment Station has made a series of experiments to determine the effect of the hydrogen ion concentration on the jelling point of mixtures of pectin, water, sugar and acid. His conclusions are as follows: (1) The formation of fruit jellies cannot be correlated with the total acidity, because the solution may contain buffer substances which reduce the hydrogen ion concentration without reducing the total acidity as determined by titration. (2) There is a direct relation between the active acidity, or hydrogen ion concentration, and the formation of jelly. The minimum hydrogen ion concentration at which jelly formation occurs is PH 3.46, a value which is independent of the nature of the acid used. (3) The presence of neutral salts probably reduces slightly the minimum hydrogen ion concentration at which jelly will form. (4) Jelly formation occurs irrespective of the amount of pectin present, once the minimum hydrogen ion concentration is reached, provided, however, the quantity of pectin present must be equal to the minimum amount necessary to produce jelly. (5) The character of the jelly is also determined by the hydrogen ion concentration. It becomes stiffer as the hydrogen ion concentration increases. Syneresis ("weeping") occurs when the hydrogen ion concentration is greater than a PH of 3.1. (6) There is a stoichiometrical relation between pectin and the combining power of the acids. (7) Tartaric acid is probably the most effective of the acids commonly present in fruit juices and citric the least effective. (8) The hydrogen ion concentration of fruit juices depends upon the character of the acids present and upon the buffer action exerted by the juice, pectin itself exerting an appreciable buffer action.

Tarr found that many different acids could be used to cause jelling of mixtures of pectin, acid, sugar and water and in all cases the jelling point could be correlated with the hydrogen ion concentration as noted above.

Packaging and Preservation.—A wide variety of sizes and shapes of containers are used for jellies. In the household, uncovered jelly glasses holding 4 or 6 ounces of jelly are the usual containers. The jelly is poured hot into the glasses and is sealed with hot melted paraffin and a high concentration of sugar is relied upon for preservation. Loss by molding is frequent, especially if the paraffin seal is not perfect. If the paraffin is added scalding hot it will sterilize the surface of the

jelly, but a paraffin coating is rarely so perfect that it will exclude microorganisms.

At one time commercially prepared jellies were preserved very generally by the use of sodium benzoate. Since public sentiment has turned against food products containing preservatives, manufacturers have adopted pasteurization. Jelly preserved by pasteurization need not be concentrated to as high a sugar content as that not so treated and the saving in sugar may often pay for the added cost of pasteurization.

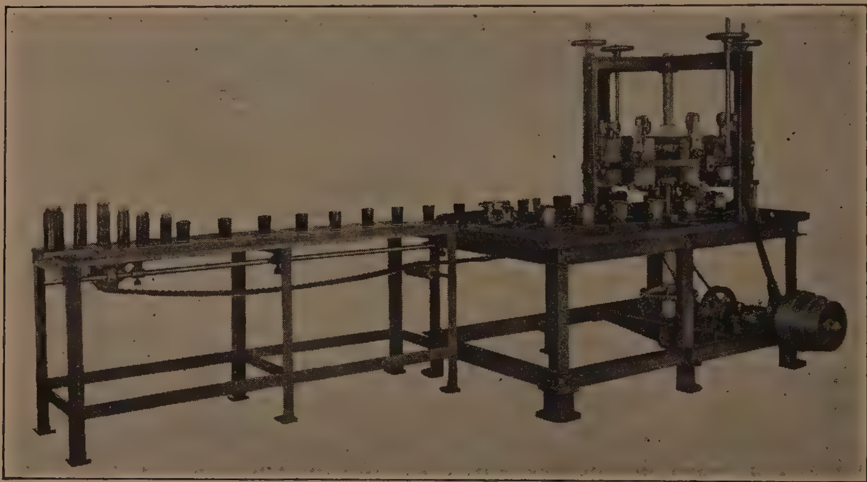

Fig. 64.—Filling machine for jars. (*Courtesy, The Elgin Machinery Co.*)

Cooling.—In many factories the jelly is cooled as soon as the end point is reached in order to prevent unnecessary injury to color and flavor by prolonged heating. A shallow copper trough fitted with a water jacket, in which cold water is circulated, is used and the jelly is stirred with a wooden paddle to hasten cooling.

Filling Machines.—Automatic filling machines which measure a definite volume of jelly into each container are in general use in large factories. They greatly reduce the cost of filling as compared with that of hand filling and give more uniform net contents.

Sealing.—Two types of vacuum-sealed jars are in common use. In one of these the seal between the glass and jar cover is made with a rubber composition ring attached to the cap. This composition melts during pasteurization and after cooling of the jar and contents, solidifies to form an airtight seal. The lid must be held in place with a clamp during pasteurization. The second style of jar is sealed with a rubber gasket similar to a fruit jar rubber but this rubber is pressed against the sides of the jar rather than the top. It is held in place by friction and the cap is rolled in much the same manner as an ordinary

sanitary can top. The cap needs no clamp to hold it in place during pasteurization.

Canning.—Small jam cans (6- to 8-ounce size) and gallon cans are sometimes used for jelly, the former size for sale for family use and the latter for bakers' use. Wooden tubs or buckets are often used for cheap jellies for bakers' use, the product usually being preserved with sodium benzoate. If cans are used for jellies made from fruits of red color, the inside of the cans should be heavily lacquered to prevent bleaching of the color by tin salts.

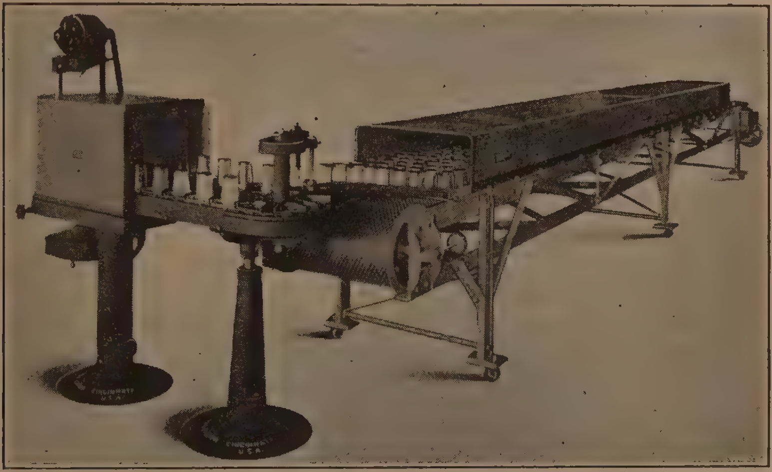

FIG. 65.—Washing and drying equipment for jam and jelly glasses. (*Courtesy, The Karl Kiefer Co.*)

Pasteurizing.—Containers sealed scalding hot (*e.g.*, 185 to 212°F.) need not be pasteurized, as the hot jelly itself will sterilize the container. Usually, it is not feasible on a commercial scale to fill all of the containers of a given lot of jelly at such a high temperature, and pasteurization therefore becomes necessary. In some large plants a continuous pasteurizer is used, in which the glasses of jelly are carried by means of a woven wire cloth conveyor through a tank of water maintained at the pasteurizing temperature. The temperature is held constant by means of a thermostat similar in operation to those described for the regulation of sterilizers for canned foods.

A temperature of 180°F. and a time of 30 minutes is usually sufficient. If the jelly is filled hot into the glasses the pasteurizing time may be shortened; if the glasses are of large size or filled cold, a longer period may become necessary. Heat penetration tests should be made by the manufacturer in order to determine the necessary length of the pasteurizing accurately for each size of container.

Some continuous pasteurizers are equipped with a device for cooling the jars after pasteurization. This may consist of several tanks of progressively decreasing temperature, through which the jars pass, or of a series of sprays of water of progressively decreasing temperature. If allowed to stand hot for several hours the jelly will be materially injured in flavor and color.

Yields.—The yield of jelly from a given variety of fruit will vary with its maturity and other conditions. Repeated extractions of the pulp will greatly increase the yield of jelly as compared with that obtained by a single extraction. In semi-commercial scale experiments in the Fruit Products Laboratory at the University of California, yields of 350 gallons of jelly per ton from citrus fruits and 300 gallons of jelly per ton from sour berries are not uncommon.

PREPARATION OF MARMALADES

A good marmalade should be a jelly with pieces of fruit suspended therein and should not be merely a jam or butter. The principles of jelly making, therefore, apply also to the preparation of marmalade.

Types of Marmalade.—English and Scotch marmalades are usually made from the bitter varieties of oranges from Spain, grown principally in the vicinity of Seville. In America sweet varieties are used.

English Marmalade.—The fruit from which the English type of marmalade is produced is high in both acid and pectin and no difficulty is experienced in obtaining a firm jelly-like marmalade from it.

The fruit may be shipped in boxes or in bulk to the factories in England, or it may be shipped in barrels in brine or in cans sterilized in sliced or shredded form in its own juice. The last named method is successful and probably the most satisfactory.

American Marmalade.—In the United States, marmalade is usually made from cull oranges of the shipping varieties, such as the Navel and Valencia. The product is characterized as "sweet marmalade" as distinguished from the bitter English marmalades. The sweet oranges grown in California and Florida for the fresh market are usually somewhat deficient in acid or pectin, or both, when allowed to ripen thoroughly. It is, therefore, usually desirable to mix grapefruit or lemons with the oranges, in order to furnish pectin and acid. Marmalade in which grapefruit is used is bitter and resembles the English product to a small degree. Those who have been accustomed to the English marmalade prefer the orange-grapefruit type to the orange-lemon type of marmalade, but the average American consumer usually prefers the sweet marmalade.

Deciduous Fruit Marmalades.—Marmalades are also made from other fruits, although many so-called marmalades are jams rather than

marmalades. Various sliced fruits can be mixed with a juice rich in pectin and sugar in preparing a true marmalade, *i.e.*, a jelly in which are suspended pieces of fruit. The famous "bar-le-duc" of France is essentially a marmalade prepared from currants.

Preparing the Juice for Marmalade.—According to the usual American factory practice in making marmalade the juice and the sliced fruit are prepared separately and are not mixed until the final boiling of the juice and fruit with sugar.

Slicing.—In preparing a marmalade from oranges and lemons these fruits are mixed in the proportion of about 1 pound of lemons to 4 to 10 pounds of oranges and sliced about $\frac{3}{16}$ inch thick. Ripe fruit of both varieties is used. In investigations by Lal Singh[18] it was proved that better results are obtained if the ratio of lemons to oranges is increased to equal weights of the two fruits. The flavor is more pleasing and a higher yield of finished product is obtained with this increased proportion of lemons.

Boiling.—The sliced fruit is covered with two to three times its volume of water in a jelly kettle (glass-lined equipment is to be preferred) and the mixture is boiled until the fruit is tender, usually about 1 hour. It is sometimes necessary to add water during boiling to replace that lost by evaporation.

The hot pulp is then pressed in a rack and cloth type of press. Heavy cloths or two thicknesses of ordinary press cloths should be used in order to eliminate as much of the fine fruit pulp as possible.

Filtration.—The juice can be cleared by settling in shallow vessels for 24 hours or by filtration through filter pulp. Felt bag filters yield a juice which is opalescent but which, nevertheless, produces a marmalade of satisfactory appearance.

Analysis of Juice.—The juice should be tested for acidity and pectin; should give a good pectin test and should contain at least 1 per cent of acidity expressed as citric acid. It is possible to use the Balling test as a method of factory control in determining the suitability of the juice for marmalade manufacture. If equal weights of lemons and oranges have been used, the juice should test about 6° Balling at 15.5°C. (60°F.), if it is desired that an equal weight of sugar and juice be used.

Grapefruit equal to 10 to 25 per cent of the weight of oranges used is frequently mixed with the latter fruit in the preparation of juice for bitter marmalade.

Preparing the Sliced Fruit.—For the preparation of the English marmalade the whole fruit is used and the juice and peel are not prepared separately. The fruit is very finely shredded by a special machine designed for this purpose.

Three methods of preparing the peel are in use in marmalade factories in California. In one method a band of peeling about 1 inch wide is cut

from the orange around its greatest circumference. This band is then cut crosswise into very thin slices about $\frac{1}{32}$ of an inch thick. The pieces possess a "shoe peg" appearance and give a very attractive marmalade.

In another method the whole fruit is sliced very thin and boiled until tender. It is then placed on screens and the white pulp is washed from the peels by a spray of water.

In one large factory the whole fruit is chopped finely by means of a mechanically driven mincemeat chopping bowl. No attempt is made in this case to prepare the juice and peel separately, in this respect resembling the English process. Marmalade prepared according to this method is cloudy and of jam-like rather than jelly-like consistency, but is of excellent flavor.

The writer prefers the second process, because of its convenience and of the attractive appearance of the finished marmalade.

Boiling and Packing.—In the usual process in California factories the juice and peel are combined after the latter has been boiled in water until tender. The proportion of peel to juice will depend upon the pectin content of the juice and upon the thickness of the peels. Where the slices are very thin and the juice is rich in pectin about 5 to 7 per cent of the sliced peels may be added to the juice together with an equal weight of sugar. If the slices are relatively thick a larger proportion by weight of peel can be added.

Where the whole chopped or sliced fruit is used without previous separation of the peel and juice, the fruit should be boiled until tender before sugar is added.

Addition of Sugar.—The amount of sugar that is required varies greatly with the composition of the juice and, as in jelly making, a relatively greater proportion of sugar can be added to juices rich in pectin and acid than to those deficient in one or both of these constituents. Equal weights of juice (*i.e.*, juice and fruit) and sugar is the normal proportion.

End Point.—The juice, peel and sugar or sugar and sliced or chopped whole fruit are boiled to the jelling point, usually 220 to 221°F. The tests previously described for determining the finishing point of jellies can be used in the case of marmalades. A good marmalade should not be syrupy, but should be of jelly-like consistency.

Cooling.—Marmalade should be allowed to cool partially and to stand a short time to permit absorption of sugar by the peel from the surrounding syrup before the marmalade is placed in the final containers, unless the whole fruit is used without previous separation of juice and peel. If packed boiling hot direct from the jelly kettles the peels are apt to come to the surface instead of remaining in suspension.

Flavoring.—The boiling of marmalade removes a great deal of the orange oil from the peels and the finished product, if made from com-

mercial sweet varieties of oranges, is liable to be lacking in distinctive flavor. A small amount of orange oil or orange extract added to the marmalade and mixed with it thoroughly after the boiling has been completed will usually considerably improve the flavor.

Pasteurizing.—The marmalade should be sealed in glass or tin at about 150 to 180°F., as described elsewhere for jellies. Vacuum-sealed containers are best for the purpose, because they reduce the tendency of the product to oxidize. They should be pasteurized in water at 180°F., as described elsewhere for jellies.

Other Marmalades.—Excellent marmalade can be prepared by combining apple juice rich in pectin and acid with thinly sliced firm peaches, or figs similarly prepared or with other firm fruits. The juice and sliced fruit can be mixed with sugar and concentrated to the jelling point in the usual manner.

VACUUM CONCENTRATION OF JELLIES AND MARMALADES

Jellies and marmalades cooked in open kettles lose a large proportion of their flavor, aroma and color by hydrolysis and evaporation and the color of red juices becomes brown if the boiling is prolonged, or if the jelly is concentrated too far.

The flavor and color of the fresh juice can be retained almost perfectly if the jelly is concentrated in vacuo. Many commercial manufacturers of jelly and orange marmalade are now using vacuum pans successfully in regular factory practise.

One difficulty that has been encountered has been the tendency of vacuum-cooked jellies to develop sugar crystals but this difficulty can be overcome by boiling the sugar with a small amount of citric acid to hydrolyze it partially before it is added to the fruit juice.

It is necessary to make frequent tests of the Balling degree or specific gravity of the mixture during boiling. Samples can be drawn from the pan by means of a sampling cock placed near the bottom of the pan.

For juices of red color, glass-lined equipment should be used in order to avoid injury to the color by contact with metals.

JELLY AND MARMALADE JUICES

Jelly manufacturers often preserve jelly juice by canning. Shredded oranges and juice are similarly preserved for shipment from Spain to England for the preparation of marmalade. The same method could be employed to advantage in the production, preservation and sale of jelly juices and marmalade juice for the use of housewives in making jelly and marmalade in the home.

Semi-commercial quantities of these products have been prepared in the Fruit Products Laboratory of the University of California and offered for sale to the local public with very encouraging results. Citrus

fruit juices were canned; other juices were bottled, because cans did not withstand the action of the juice.

For the use of housewives the juices must be partially concentrated before canning in order that there may be no difficulty in obtaining good jelly or marmalade. No sugar need be added to the juices at the time of canning.

USE OF DRIED FRUITS IN THE PREPARATION OF JELLIES AND MARMALADES

Large quantities of dried apple peels and cores from evaporating plants and of dried pomace from apple cider and vinegar factories are used in the commercial manufacture of cheap jellies for bakers' use. The apple juice is prepared by soaking the dried material overnight, followed by boiling, pressing and filtering as for the preparation of juice from the fresh fruit. It is then usually combined with berry juice or red grape juice; or artificial flavor and color are added.

Oranges and lemons can be dried and used for the production of marmalade and jelly and loganberries are often dried in prune evaporators and used for jelly making. The dehydration of these and other fruits does not materially impair their jelling quality, although there is some change in flavor and slight darkening of the color.

CAUSES FOR FAILURE IN JELLY MAKING

Too Much Sugar.—The usual cause for failure is the addition to the juice of too much sugar in proportion to the pectin and acid of the juice. Firm jelly can be obtained by properly adjusting the proportion of sugar to the pectin and acid as previously determined by the alcohol test for pectin and by titration of the acidity.

Prolonged Boiling.—Too prolonged boiling results in the hydrolysis of the pectin and in the formation of a syrupy caramelized mass that will not jell. The juice and sugar should be concentrated to the jelling point as rapidly as possible in order to avoid hydrolysis of the pectin.

Crystals.—At ordinary temperatures jelly develops sugar crystals if the concentration of the finished product exceeds 70° Balling. During the normal boiling of jelly some of the cane sugar is hydrolyzed to dextrose and levulose, which exhibit less tendency than cane sugar to crystallize.

Crystals of cream of tartar form in grape jelly, but this tendency can be reduced if before the addition of sugar the juice is concentrated by boiling and allowed to deposit its excess cream of tartar in storage. It may also be diluted with water and fortified with commercially prepared pectin or with other fruit juices to the point where crystallization does not occur when jelly is prepared.

RECIPES

It is believed that the student will be able to prepare jelly and marmalade satisfactorily, provided the general principles and processes discussed in this chapter are followed. Many good recipes are to be found in Government and Experiment Station publications. Two or three tested recipes only will be given to serve as illustrations.

Berry Jelly.—Use sour berries, such as loganberries, currants, sour varieties of blackberries, etc. Crush. Heat to boiling in their own juice for 3 minutes. Press through a heavy cloth. Strain through felt or filter through pulp until clear. Test pectin content of the juice by mixing one spoonful of the juice with an equal volume of 95 per cent grain alcohol. If the mixture forms a stiff jelly, add 1 pound of sugar to each pint of juice; if a soft jelly-like mass forms, use about ¾ of a pound of sugar per pint of juice; and if small separate lumps of a pectin precipitate form, use ½ pound or less of sugar per pint of juice. Heat slowly and stir until the sugar dissolves. Boil rapidly until a boiling point of 220°F. is reached. If jelly is made on a small scale pour into glasses and seal; if on a large scale, cool to about 150°F., seal in glasses and pasteurize at 180°F. for 30 minutes.

Apple Jelly.—Use sour fruit. Crush or slice. Add water to cover. Boil 20 minutes. Press. Filter. Test for pectin and proceed as for berry jelly.

Marmalade from Sweet Oranges and Lemons.—Use equal weights of lemons and oranges. Slice about ⅛ inch thick. Add about three volumes of water. Boil 1 hour. Press. Strain to remove coarse pulp. Filter. Determine Balling degree and make necessary temperature correction. If Balling is above or below 6° Balling add water or concentrate by boiling, as the case requires, until this Balling is approximately attained. Cut the ends from oranges and discard the ends. Slice the remainder of the orange into very thin pieces. Boil in water until tender. Drain off the juice but do not press the fruit. Wash the cooked shreds under a vigorous jet of water to remove fine pulp. Combine the residual peel with the juice prepared from the oranges and lemons above, in the proportion of about 1 pound of sliced peels to 10 pints of juice.

If the juice exhibits a good pectin test, add an equal weight of sugar and concentrate to the jelling point as directed for berry jellies. Allow to stand for about 30 minutes to permit equalization of the sugar in the peels. Pack into glass or tin containers at about 150 to 170°F., and seal. Pasteurize as directed for berry jellies.

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CHAPTER XVIII

FRUIT JAMS, BUTTERS, PRESERVES AND CONFECTIONS

Fruit jams, butters and preserves are very generally used through the civilized world. The people of the British Empire are probably the most important manufacturers and consumers of jams; France is noted for preserved and candied fruits of high quality; China produces preserved ginger root and candied fruits, which are well-known articles of world commerce, and India is famous for a fruit relish known as "mango chutney."

Housewives pride themselves upon their preserves and jams and probably a greater quantity of fruit is used for these purposes in the home than is used in the factory production of jams and preserves.

DEFINITIONS

The definitions given below conform to the usual conceptions of the products in question.

Jam.—Jam is prepared by boiling the whole fruit pulp with sugar (sucrose) to a moderately thick consistency without retaining the shape of the fruit. The United States Government Pure Food Regulations require the use of not less than 45 pounds of fruit to each 55 pounds of sugar.

Fruit Butter.—This product is prepared by boiling the screened fruit pulp with or without the addition of sugar, fruit juices and spices to a semi-solid mass of homogeneous consistency. It differs from jam in being of higher concentration and finer consistency. It is usually heavily spiced and is frequently prepared without the addition of sugar.

Fruit Paste.—Fruit paste or fruit leather, etc., is prepared as described for fruit butter but is dried in the sun or by artificial heat to a solid consistency or to approximately the consistency of putty.

Fruit Preserves.—Preserves are made by cooking the prepared fruit in sugar (sucrose) syrup until the concentration of sugar reaches 55 to 70 per cent. The fruit should retain its form, should be crisp rather than soft, and should be permeated with the syrup without shriveling of the individual pieces. Government regulations require the use of not less than 45 pounds of fruit for each 55 pounds of sugar.

Candied Fruits.—Candied fruits are prepared by gradually concentrating fruits in syrup by repeated boilings until the fruit is heavily

impregnated with sugar, this process being followed by drying to overcome stickiness. Glacé fruit is prepared by coating candied fruit with a concentrated solution of sugar followed by careful drying to give a transparent glaze to the surface.

Fruit Confections.—This is a general term used to describe candies in which fruits are used. A large number of products of this character are on the market, which vary greatly in appearance, texture, flavor and in the proportion of fruit used in their manufacture.

JAMS

Jam may be made from practically all varieties of fruits and from some vegetables. In the United States and in the British Empire the small fruits and berries are most popular for the purpose.

Various combinations of different varieties of fruits can often be made to advantage, pineapple being one of the best for blending purposes because of its pronounced flavor and acidity.

Preparation of the Fruit.—Fruit for jam making should have reached full maturity in order to possess a rich flavor and be of the most desirable texture.

All berries must be carefully sorted and washed; strawberries must be stemmed; peaches, pears, apples and other fruits with heavy skins must be peeled; while apricots, plums and other thin-skinned fruits do not require peeling.

Firm fruits should be boiled in a small quantity of water before sugar is added in order to facilitate pulping. In factory practice it is possible to pulp boiled or steamed fruit in a tomato pulper without previous peeling. Stone fruits, such as plums and apricots, require a very heavy pulping screen because of the abrasive action of the pits. The paddles should operate at moderate speed, so that the pits will not be broken into fine fragments.

Berries should not be softened by boiling before the addition of sugar but need only be crushed.

Addition of Sugar.—Pure fruit jam as defined by the Pure Food and Drug Regulations contains only fruit and cane sugar. Glucose may also be used but its use must be declared upon the label.

The proportion of sugar to fruit varies with the variety of the fruit, its ripeness and with the effect desired, although the most common ratio of sugar to fruit is pound per pound. This is usually a suitable ratio for berries, currants, plums, apricots, pineapple and other tart fruits. Sweet fruits of low acidity, such as ripe peaches, sweet prunes and Vinifera varieties of grapes, normally require less than an equal weight of sugar and the ratio may in some cases be as low as ¼ pound of sugar per pound of fruit.

Boiling.—Boiling is desirable in order to cause intimate mixing of the fruit pulp and the sugar and partially to concentrate the product by evaporation of excess moisture.

Berries should be used in small lots and concentrated to the desired consistency as rapidly as possible. Other fruits are more resistant to the action of heat and may be boiled more slowly or in larger lots.

Steam-jacketed copper kettles are commonly used in commercial practice for the preparation of jams, small kettles being preferred.

End Point.—Most jams should be concentrated to a boiling point of 218 to 221°F., the end point varying with the fruit variety, proportion of sugar and other factors. A jelly thermometer may be used with advantage to determine the end point of the boiling process.

Use of Pectin.—The combining of fruit pulp with pectin or with apple juice is becoming a more general practice in the commercial manufacture of fruit jams, in order to obtain products of jelly-like consistency.

The use of fruit pectin is of doubtful value, particularly from the consumer's standpoint, because it permits of great dilution of the fruit pulp with water and sugar and masks the jam-like character of the product.

Vacuum Concentration.—Concentration of berry jams in an open kettle results in considerable loss of color and flavor. Experiments and recent commercial developments have demonstrated that a jam of fresh berry flavor and rich red color and in every respect superior to kettle-cooked jams can be made by concentrating the fruit pulp and sugar in a vacuum pan (see vacuum concentration of jellies in Chapter XVII).

The capacity of the vacuum pan will be greatly increased if the fruit and sugar are heated to boiling in an open kettle before entering the vacuum pan. If desired, the vacuum pan may be used as an open kettle when the fruit and sugar are first added. This will be necessary for firm fruits that have not been previously subjected to boiling at atmospheric pressure.

Although greater skill is required in the operation of a vacuum pan than a jelly kettle, the output per man can be greatly increased where vacuum concentration is substituted for the open-kettle method of preparing jams, jellies and preserves and superior products obtained.

Packaging.—A great deal of the jams produced in the British Empire is sold in cans ("tins") while in America the glass container is almost universally used for jams, jellies and preserves. The processes of filling and sealing are done by automatic machinery, as described for jellies.

Pasteurizing.—If the product contains a very high concentration of sugar (70 per cent or above) it will not spoil in most climates. Most commercially prepared jams are not concentrated to this high density, however, and should be pasteurized at 180°F. for 30 minutes as described for jellies, in order to prevent molding or fermentation.

Cooling before Placing in Containers.—If allowed to stand at a high temperature too long before packaging and pasteurizing, fruits of delicate color and flavor, such as strawberries, may be injured in quality. Such jams should be cooled as described for jellies.

FRUIT BUTTERS

The most important fruit butter produced in the United States is apple butter; peaches and plums are used to a limited extent for the same purpose. In continental Europe plums and prunes are used in very large quantities for the preparation of cheap butters and highly concentrated jams and in Asia Minor the apricot is quite generally used for the purpose.

Preparation of the Fruit.—In the commercial manufacture of apple and pear butters the fruit is cooked until soft with a small amount of water and without previous peeling or coring. The softened fruit is then passed through a tomato pulper to remove skins and seeds and generally through a tomato pulp finisher to impart a smooth texture.

An apple crusher may be used to crush the fruit before boiling and pulping.

Peaches should be peeled before pulping, and other stone fruits, such as apricots, prunes and plums, should be pitted, although it is possible to pulp these fruits if very heavy screens are used in the pulping machine. All fruits should be thoroughly cooked before pulping.

One essential difference between a jam and a butter lies in the screening of the pulp used for the latter.

Preparation of Fruit Butter without Adding Sugar.—In the household and orchard scale preparation of apple butter, apple juice or apple syrup is often used to replace sugar, but the butter so produced is of a tart flavor. The cider may be added with or without previous concentration, the usual ratio being 1 gallon of fresh juice per gallon of pulp.

The cider and sauce are concentrated by rapid boiling to a thick consistency and spices are added near the finishing point.

Spices.—The usual spices are cinnamon, cloves and allspice, used in the proportion of about 1/10 per cent each. A small amount of ginger and vanilla extract or nutmegs also often used.

It has been found that a great deal of the essential oils of the spices will be lost if the spices are added before concentration is nearly completed. On account of its thick consistency it is necessary to stir the butter thoroughly after the addition of the spices.

End Point.—The finishing point is determined by consistency rather than by boiling point because the boiling point of the finished butter is dependent upon the ratio of pulp to juice and of pulp to sugar. The butter, when cold, should be thick enough to stand when a spoonful is placed on a plate and should not flow. It should, however, be thin enough to spread easily on bread.

Fruit Butters with Sugar.—In the preparation of fruit butters from pears and peaches, sugar is generally used instead of fruit juice. Brown sugar is often substituted for refined sugar because a finished product of dark color is usually desired.

The usual proportion is ½ pound of sugar per pound of pulp. The mixture is then concentrated to a heavy consistency and spiced as described above.

A process employed at the University of California for the manufacture of the pear butter above mentioned is as follows: The ripe fruit is carefully sorted and trimmed. It is crushed in an apple crusher and then boiled with a small amount of water until soft. The softened fruit is passed through a tomato pulper and subsequently through a tomato finisher. To each pound of the pulp is added ½ pound of sugar. The mixture is concentrated to 218°F. and approximately ½ gallon of lemon juice is added per 10 gallons of original pulp. The mixture is then boiled to 221°F. and 1/10 of a pound each of ground cloves, cinnamon and ginger and one-half this amount of nutmeg are added per 10 gallons of original pulp. The boiling is continued for a short time, less than 3 minutes. The butter is canned and sealed hot, no further sterilization being required.

Plums and other sour fruits can be made into butters by the same formula with the exception that the lemon juice is omitted. Peach butter is improved by the addition of lemon juice as described above for pear butter or by mixing the pulp with that from plums or other sour fruit.

Preservation.—Fruit butters require no sterilization if packed boiling hot and sealed at once; or if concentrated to a boiling point of 221°F. or higher, but under other conditions require pasteurization as described for jellies.

Butters that have been highly concentrated may be preserved satisfactorily by placing them in scalded jelly glasses, stoneware jars, etc., and sealing with paraffin.

PRESERVES

Fruit preserves of good quality should retain the form of the original fruit and should consist of the whole or cut fruit in a clear syrup of high sugar concentration. The fruit should not be caramelized by overcooking and should retain most of the color of the fresh fruit.

Preparation of the Fruit.—Fruit is prepared for preserving as for canning.

Open-kettle-one-period Process.—The usual process for the preparation of fruit preserves consists in boiling the fruit in steam-jacketed kettles with sugar or in syrup until a syrup of heavy density is obtained and the fruit is thoroughly impregnated with the syrup.

Firm fruits, such as peaches, pears, figs, etc., require a long period of boiling in order to impregnate them with the syrup, while berries should be boiled only a very short time in order that the fruit shall not be badly softened.

The end point of the boiling process is most conveniently determined by means of a thermometer as in the preparation of jelly. The syrup should have a final concentration for most fruits of 60 to 65° Balling, or the boiling point of the finished product should be approximately 220°F.

Fig. 66.—Convenient rack for transferring berries or other fruit in a preserving factory.

The objection to the open-kettle-one-period process is that it often results in serious injury to the flavor and color of the finished product. Its advantage lies in its rapidity and low cost of operation.

The Slow Open-kettle Process.—In order to avoid undue injury to the color and flavor of the fruit, the slow process of preserving may be employed in which the fruit is heated for a short time on successive days in syrups of progressively increasing sugar concentration.

It is customary to place the fruit first in a solution of 39 to 40 per cent sugar and boil long enough to render the fruit tender but not soft. The mixture is then set aside for 24 hours. More sugar is added to increase the sugar concentration about 10 per cent above that of the first syrup. The mixture is then boiled a short time, usually 3 or 4 minutes, and is set aside again for 24 hours. The process is repeated until the product is of the desired consistency. It is then placed in the final containers and sterilized.

Vacuum Cooking of Preserves.—The advantages enumerated for the vacuum cooking of jams apply equally well to the vacuum cooking of preserves.

Fruit that is to be cooked in vacuum should first be cooked sufficiently at atmospheric pressure to render it tender.

For firm fruits concentration must be slow in order to permit penetration of the fruit by the syrup. Soft fruits may be concentrated rapidly.

The finishing point is determined by the Balling test of samples of the syrup withdrawn while boiling is in progress. There is danger of concentrating the syrup to such a point that crystallization of the

cane sugar occurs and the final concentration should not exceed 65° Balling.

Vacuum-cooked preserves are superior in flavor and color to preserves made in an open kettle.

Cooling of Preserves.—In order to retain the fresh flavor and color of the fruit most satisfactorily the preserved fruit should be cooled as soon as possible after the cooking process is completed.

Sterilizing.—If filled into the jars or cans boiling hot, or if concentrated to more than 65° Balling, preserves need not be sterilized in the container, but in commercial practice it is generally desirable to pasteurize as described for jellies.

Preserving Methods for Various Fruits.—The processes of preparing preserves from various fruits differ considerably in important details, and it is therefore deemed advisable to give brief descriptions of the more common methods followed in preserving some of the more important fruits.

Strawberries.—Use firm ripe berries of good color. Sort carefully and stem. Place in a preserving kettle with an equal weight of sugar. Heat slowly to the boiling point with gentle stirring. Avoid crushing of the fruit. Boil 3 to 4 minutes. Chill to room temperature as quickly as possible on a cooling table or by circulating cold water in the jacket of the kettle. Allow to stand with occasional gentle stirring until the berries have thoroughly absorbed the syrup and have ceased to float. This may require several hours.

Pack into glass jars and seal jars in a vacuum sealer. Pasteurize in water at 180°F. for 30 minutes. Cool to room temperature as rapidly as the glass will permit.

In the vacuum cooking of strawberries place the berries and sugar in a vacuum kettle equipped with a stirring device. A small amount of water should be added to prevent crushing of the berries by the stirrer. Heat to boiling in the open kettle for about 2 minutes to soften the berries and thoroughly dissolve the sugar. Place the kettle under vacuum and concentrate to a 60° Balling. Release vacuum; withdraw berries; pack into jars and pasteurize as directed above. Cool pasteurized jars at once. The principal danger in the vacuum cooking of berry preserves lies in the fact that, if concentrated too highly, cane sugar will crystallize in the finished product.

Other Berries.—Other berries may be preserved in the same manner as described for strawberries, although they are not as liable to soften and disintegrate as are the latter and will usually withstand more vigorous and longer boiling than will strawberries.

Fig Preserves.—A number of methods are in commercial use for preserving figs. In Texas the Magnolia variety of fig is used. The fruit is lye peeled in boiling dilute lye (usually about 1 per cent sodium hydroxide) and is rinsed under sprays of water. It is placed in a dilute syrup of

approximately 30° Balling, slowly concentrated by boiling in open kettles to 60 to 65° Balling, packed hot in jars or cans and sealed at once. Sterilizing in the container is usually omitted.

In California the slow process is frequently used. The figs, usually of the Kadota variety, are blanched in water near the boiling point until tender. They are then boiled a short time in dilute syrup or are heated to 185°F. and then set aside for about 12 hours. On succeeding days the syrup concentration is progressively increased and the heatings repeated until the desired consistency is obtained.

In another process the blanched fruit is placed in syrup at 180 to 190°F. and this temperature is maintained for about 2 hours, during which period the sugar concentration is increased by the addition of sugar which is dissolved by stirring. The fruit is then set aside in the syrup overnight and packed. The finished product is of very attractive appearance and flavor.

Single-period boilings of the fruit in open kettles are also commonly used, but result in considerable breaking of the fruit and rather heavy loss during sorting and packing. The boiled fruit should be allowed to stand overnight to absorb the syrup before packing. The broken fruit must be used for jam, which is sold at a lower price than the preserves.

Vacuum cooking of fig preserves has not been used commercially to the writer's knowledge, although small-scale laboratory tests indicate that vacuum cooking has possibilities. During the harvesting season a large proportion of the figs are canned in water and later used for preserving.

Peaches and Pears.—These fruits are peeled and cored or pitted as for canning. Peaches may be lye peeled, the whole lye-peeled unpitted peaches being very attractive when preserved.

The prepared fruit is placed in a syrup of approximately 30 per cent sugar and is boiled slowly to the desired concentration. This will be for peaches about 55 to 60° Balling and for pears about 50° Balling (corrected for temperature). If placed in too concentrated a solution the fruit will shrivel and become tough. The use of a dilute syrup for the preliminary stages of the process softens the fruit and permits penetration of the fruit by the syrup.

A modification of the above process consists in boiling the fruit in water until tender, followed by the addition of sugar and a small amount of water to give a heavy syrup in which the fruit is cooked a short time.

Cherries.—Artificially colored and flavored cherries are preserved in large quantities as Maraschino cherries.

The cherries, usually Royal Anne variety, are placed without stemming in barrels and the barrels are filled with a dilute solution of sulphurous acid, usually $\frac{3}{10}$ to $\frac{5}{10}$ per cent SO_2. It has been found that a $\frac{5}{10}$ per cent solution of sodium metabisulphite can be substituted for the

sulphurous acid solution. The barrels are sealed and stored until the fruit is needed for preserving. The sulphurous acid bleaches the fruit, hardens the tissues and will preserve it for at least a year.

In preparing the preserved cherries the stems are removed and the fruit is pitted carefully with hand pitters or with a special form of mechanical pitter. The fruit should be lacerated as little as possible.

The cherries are heated in repeated changes of water until all taste of sulphurous acid is removed and the fruit is then cooked in water until tender.

In some factories the fruit is colored by soaking in water colored with permissible red coal tar colors. A combination of Amaranth and Ponceau-3-R coal tar colors can be used to give the desired tint. In other factories the colors are added direct to the first syrup used in the preserving process. An excess of the artificial colors should be avoided so that the flavor of the fruit may not be impaired.

A syrup of approximately 30° Balling is first prepared. This may consist of one part confectioners' glucose to two parts of cane sugar or may be prepared from cane sugar. The fruit is boiled in this syrup for 3 or 4 minutes and is set aside for 24 hours. The syrup is then on successive days increased by the addition of sugar or of sugar and glucose to 40 to 50° Balling.

A fresh syrup of 45 to 50° Balling flavored with a small amount of bitter almond extract or bitter almond oil is prepared and placed on the fruit in small glass preserve jars or in lacquered cans. If cans are used, these are exhausted and sealed in the usual manner and sterilized at 212°F. about 30 minutes; if in glass, the containers are sealed in vacuum and pasteurized as described elsewhere for jellies and preserves. The caps should be lined with lead foil or other material not affected by sulphurous acid.

Fresh cherries may also be preserved without the use of sulphurous acid and artificial coloring and flavoring by a process similar to that given for figs. Maraschino cherries are often preserved in glass with $\frac{1}{10}$ of 1 per cent of sodium benzoate.

Spiced Preserves (*Sweet Pickles*).—Spiced preserves are prepared principally on a household scale, but it is believed that their manufacture upon a commercial scale should provide a considerable outlet for fruits suitable for preserving purposes.

Peaches, pears (particularly small varieties such as the Seckel), figs, quinces and other firm fruits are those most commonly used for sweet pickles.

The fruit is prepared as described elsewhere for sweet preserves, boiled in water until tender, when they are then placed in a spiced syrup. The formula given below is typical of the syrups used for the purpose.

Sugar	1,400 grams or 14.0 pounds
Vinegar (cider vinegar of 4 per cent acetic acid)	475 cubic centimeters or 5.0 pints
Water	475 cubic centimeters or 5.0 pints
Ginger root, broken	7 grams or 1.0 ounces
Whole cloves	10 grams or 1.5 ounces
Stick cinnamon	15 grams or 2.0 ounces

The fruit is heated to boiling in this syrup and allowed to stand overnight. The syrup is then increased to 60° Balling by the addition of sugar. The fruit and syrup are heated for 3 or 4 minutes and are packed boiling hot into jars or cans. Normally no further processing is necessary, although if the syrup and fruit cool to below 180°F. before packing in the final containers the product should be pasteurized at 180°F. for 30 minutes or processed at 212°F. for 10 minutes to insure against spoilage. If the spices are tied in a cheesecloth bag they may be removed from the syrup after preserving is completed.

CANDIED FRUITS

The manufacture of candied and glacé fruits has in the past been a highly specialized industry in which success has depended to a very great extent upon the skill and experience of the individual workmen. A very large proportion of the work has been done by hand labor and with small individual lots of fruit. Undoubtedly, the processes for the candying of fruits lend themselves to factory methods and existing factory equipment could be employed to greatly reduce the cost of manufacture and the price to the consumer.

General Principles.—The candying process consists essentially of slowly impregnating the fruit with syrup until the sugar concentration in the fruit is high enough to prevent spoiling. The process must be so conducted that the fruit does not soften and become jam or become tough and shriveled. Repeated boiling and storage in syrups of progressively increasing sugar concentration will accomplish the desired results.

Following impregnation, the fruit is washed and dried. It may be packed and sold in this form or it may be coated with a thin glaze of sugar —"glacéd." This is done by dipping the dried candied fruit in a syrup and again drying the surface.

Preparing the Fruit.—Frequently the fresh fruit is stored in a dilute solution of sulphurous acid in order to bleach the color, harden the tissues and to preserve it until needed—as described for Maraschino cherries.

Whole Fruits.—Fruit preserved in sulphurous acid must be thoroughly leached repeatedly in hot water to remove all taste of SO_2 before the candying process is begun. Cherries are stemmed and carefully

pitted before leaching. Apricots should be pitted without cutting the fruit in half. Small pears, plums, prunes and other whole fruits are often pricked with copper wires.

Fresh fruits can be used for candying purposes without the intermediate step of storage in sulphurous acid. Figs, peaches, pears and pineapple are particularly well suited for use fresh.

The jujube, or Chinese date, now produced in commercial quantities in the United States, is excellent for the preparation of candied fruit. The skin of the fruit must be punctured very thoroughly by means of metal needles, or slit.

Berries are very difficult to candy because of their tendency to soften.

Other fruits should be boiled in water until tender, after preparation as described above.

Use of Canned Fruits.—All firm varieties of canned fruits may be used very satisfactorily, the pineapple being particularly desirable for the purpose.

Firm Fruit Necessary.—Frequently fruit which is at the best stage of maturity for table use is too soft for the preparation of candied fruits. Firm ripe fruit or even that which is slightly immature is better than thoroughly ripe fruit.

Syrup Treatment.—As at present practiced, the impregnation of the fruit with sugar is a process that requires a long period of time and frequent manipulation of the fruit in small containers.

Commercial practice varies greatly in regard to the application of the syrup and the process described below is general in nature, although found to give good results in experiments made upon a semi-commercial scale.

A syrup of approximately 30° Balling is first prepared by use of one part by weight of glucose, two parts by weight of cane sugar and enough water to give the desired Balling degree. The above concentration of 30° Balling will be obtained by dissolving approximately 1 pound of the mixed glucose and sugar in 2 pints of water.

Unless glucose is used the candied fruit will dry too completely and become hard and granular. The glucose prevents overdrying and also improves the appearance of the finished product by causing it to be more translucent than would otherwise be the case.

The fruit, prepared by previous treatment in sulphurous acid and boiling to render it tender, or by boiling of the prepared fresh fruit, is placed in the syrup. Canned fruits are placed in this syrup direct from the can. The fruit and sugar are boiled for a short time, 1 or 2 minutes, and the mixture is then set aside for 24 to 48 hours to permit equalization of the sugar in the fruit and syrup. Large dishpans are ordinarily employed for storage. Small steam-jacketed tilting jelly kettles are used for boiling the fruit and syrup.

If the fruit tends to float it may be submerged in the syrup by means of a floating wooden rack or wire screen.

After 24 hours' or longer storage the syrup is drained from the fruit and is made up to approximately 40° Balling by the addition of cane sugar and glucose, by weight approximately one part of glucose to each two parts of cane sugar. For the Maraschino type of candied cherries the syrup should be colored by the addition of a small amount of permissible red coal tar dye.

The fruit is brought to the boiling point in the syrup and is again set aside for 24 to 48 hours. The shorter time is preferable in order to avoid fermentation and molding. The syrup is then increased to 50° Balling in the manner described above and the fruit is brought to boiling and set aside for another 24-hour interval. The process is repeated on succeeding days, with an increase of 10° Balling each day until the syrup has reached approximately 70° Balling. Better results are obtained by increasing the syrup concentration 5° Balling, rather than 10° Balling each day.

This concentration is maintained until the fruit and syrup have thoroughly equalized in sugar concentration.

Draining and Drying.—After the syrup treatment is complete the fruit should be thoroughly saturated with the heavy syrup and should be plump and firm. It should be tender in texture and not tough or shriveled. The syrup should be free from sugar crystals and of about 70° Balling at the time the fruit is ready for drying.

The fruit is removed from the syrup and the surface washed with a wet cloth or sponge or the fruit is dipped momentarily in boiling water. It is then placed on screens to dry. Drying may be accomplished at room temperature, but takes place more rapidly and with more uniform results if done by artificial heat at a temperature of 110 to 120°F. If dried at too high a temperature the syrup may dry in the form of flakes and separate from the fruit.

The drying should be continued until the fruit is no longer too sticky to be handled. If finger marks are to be avoided the fruit should be handled with tongs or special forks.

Glacéing the Candied Fruit.—Candied fruit is frequently coated with a thin transparent coating of sugar, which improves the appearance of the product and reduces the tendency of the fruit to become overdry and hard.

Pacrette[6] gives the following process for glacéing:

Dissolve sugar in a small amount of water in a preserving kettle. Concentrate by boiling until the syrup will form air bubbles on the back of a perforated skimmer when blown upon; place the fruit in this syrup and remove from the fire; allow to stand in the syrup for about 1 minute; remove the fruit with a fork and place on screen trays to dry. Dry slowly to avoid crystallization and turn-

ing white of the coating. The fruit must be thoroughly dry at the time of dipping and small lots only should be dipped at a time. The fruit must be left in the syrup only a very short time.

A satisfactory coating can be obtained also by dipping the candied fruit in a 1 per cent pectin solution for 1 minute, followed by drying at 120°F. 2 or 3 hours.

USE OF FRUIT FOR CHOCOLATE-COATED CANDIES

Fruits lend themselves well to coating with chocolate and are used in a variety of forms for this purpose.

Chocolate-coated Frozen Fruit.—Fresh fruit has been used successfully for chocolate dipping, although only that which is very sweet meets with favor from the consuming public. The fruit may be used whole or in the form of ground pulp. In either case it is frozen and is then dipped in melted confectioners' chocolate.

The chocolate congeals at once and the dipped product must be held in a refrigerator until served.

It is possible to mix gelatin, agar-agar, pectin or other jelling material with the pulp and sugar and obtain a product which will solidify at room temperature and can be coated.

Chocolate-coated Candied Fruits.—Fruit may be candied as previously described and may then be successfully dipped in chocolate. The chocolate should be melted at not above 100°F. and should be used at about 85°F. in order to prevent streaking and whitening of the coating.

Use of Jellied Fruits for Chocolate Centers.—Chocolate centers of jelly-like consistency can be readily prepared by mixing fruit pectin with fruit pulp and sugar in the proper proportions. In commercial size experiments at the University of California various fruits were converted into pulp by boiling and pulping in a tomato pulper to remove seeds and skins. To the pulp was added enough commercial pectin, as determined by trial, to give, on concentration to 222 to 224°F. with sugar equal to the weight of fruit, a product which on cooling solidified to stiff jelly. The jelly was allowed to harden in a layer about ½ inch thick and was cut into square pieces of convenient size for coating with chocolate, cr the hot jelly was cast in starch molds and allowed to solidify.

Some of the pieces were coated by hand dipping and the remainder by means of an enrobing machine. The finished product kept well and proved popular with the candy-consuming public.

Bursting of the chocolate coatings occurred when the fruit was concentrated to 218 to 219°F., but little difficulty from bursting was encountered in centers previously concentrated to 222°F. or above. It is desirable to allow the cut pieces of jellied fruit to dry in the air for 2 or 3 days before coating with chocolate.

Use of Dried Fruits in Candies.—Dried fruits require no further concentration in most instances when used in candy. Raisins are in general use by confectioners for the preparation of chocolate-coated clusters, in which peanuts may be mixed with the raisins.

Raisins are also ground to a paste and mixed with chopped nuts and formed into pieces of convenient size, which are then dipped in chocolate.

Dates and prunes are frequently pitted and stuffed with fondant or nut meats. These fruits also yield a satisfactory candy when ground to a paste, mixed with fondant or chopped nuts and dipped in chocolate. Many dried fruits can be chopped and mixed with nougat candy successfully.

Flavoring of Cream Centers with Fruit.—Cream centers for chocolates are generally flavored artificially and colored with permissible coal tar colors. It has been found that highly concentrated fruit pulp or fruit syrup can be employed for this purpose to produce centers for chocolate coating that are superior in flavor and general quality to the imitation products made without the use of fruit.

Manufacture of Candy Bases from Fruits.—Fruit products factories could with profit investigate the manufacture of fruit syrups, fruit jams, jellified fruit products and dried fruit preparations for the use of confectioners, and probably such products would provide a large outlet for surplus fruits and improve the quality of candies.

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CHAPTER XIX

TOMATO PRODUCTS

The most important relish used on the American table is tomato catsup and southern European peoples, particularly the Italians, use a large quantity of tomato paste, a highly concentrated tomato product, of which there is a large importation into the United States from Italy. Canned tomato puree is very generally used in restaurants and hotels for flavoring and for soups. Canned tomato soup is probably the best known soup stock used in the American home. Hot sauce and chili sauce are rapidly increasing in favor.

DEFINITIONS

A joint committee representing the Association of American Dairy, Food and Drug Officials, the Association of Official Agricultural Chemists and the U. S. Department of Agriculture has recently decided upon specifications for most tomato products. These standards are followed by pure food and drug officials in the enforcement of the Pure Food and Drug Regulations and often form the basis for contracts between manufacturers. The definitions adopted are as follows:

a. **Final Definitions and Standards for Strained Tomatoes and Tomato Paste.**—1. *Strained tomatoes* is the product obtained by straining sound ripe tomatoes, raw or cooked, through a screen that removes skins and seeds.

2. *Tomato Paste* is strained tomatoes concentrated by evaporation, with or without the addition of salt, with or without the addition of basil leaf, with or without the addition of pure sodium carbonate or of sodium bicarbonate to neutralize a portion of the acidity, and contains not less than twenty per cent (20 per cent) of tomato solids determined by drying in vacuo at 70°C.

3. *Concentrated tomato paste* is strained tomatoes concentrated by evaporation, with or without the addition of salt, with or without the addition of basil leaf, with or without the addition of pure sodium carbonate, or of sodium bicarbonate to neutralize a portion of the acidity, and contains not less than thirty per cent (30 per cent) of tomato solids determined by drying in vacuo at 70°C.

4. *Strained tomatoes from trimming stock* is the product obtained by straining sound peelings, trimmings and pieces from ripe tomatoes through a screen that removes skins and seeds.

5. *Tomato paste from trimming stock* is strained tomatoes from trimming stock concentrated by evaporation, and otherwise the same as definition (2) above.

6. *Concentrated tomato paste from trimmings* is made from strained tomatoes from trimming stock concentrated and is otherwise the same as definition (3).

b. **Tentative Definitions and Standards for Tomato Pulp, Puree, Catsup and Chili Sauce.**—In the text which follows, the words "strained tomatoes" wherever used refer to strained tomatoes as previously defined:

1. *Light tomato puree* is the product obtained by the evaporation of strained tomatoes, with or without the addition of salt and contains not less than six and thirty hundredths per cent (6.30 per cent) of tomato solids determined by drying in vacuo at 70°C.

2. *Medium tomato puree*, is the product obtained by the evaporation of strained tomatoes, with or without the addition of salt and contains not less than eight and thirty-seven hundredths per cent (8.37 per cent) of tomato solids determined by drying at 70°C. in vacuo.

3. *Heavy tomato puree* is the product obtained by the evaporation of strained tomatoes, with or without the addition of salt and contains not less than twelve per cent (12 per cent) of tomato solids determined by drying in vacuo at 70°C.

4. *Ketchup, catsup, catchup* is the clean, sound product made from properly prepared strained tomatoes with spices, salt, sugar and vinegar, with or without onions and garlic, and contains not less than twelve per cent (12 per cent) of tomato solids.

5. *Chili Sauce* is the clean, sound, cooked product made from chopped, peeled, ripe tomatoes, chopped peppers, salt, sugar, spices and vinegar, with or without onions and garlic, and contains not less than . . . per cent of tomato solids. (Per cent of tomato solids not defined.)

The committee also established tentative standards for the various grades of puree from trimming stock, which correspond in per cent total solids to the percentages given above for puree from strained tomatoes.

TOMATO COLOR

Tomato products should have a deep red color, a quality which varies with the variety, the locality, maturity of the fruit and process of manufacture.

Nature of Tomato Color.—Tomato color was first separated in pure form in 1876 by Millardet,[3] who named it "solanorubin." It was again isolated by Schunck[4] in 1903, who named it lycopin, a name generally applied to it today. Montanari[5] proved that it is a hydrocarbon and Willstatter and Escher[6] have proved that lycopin is an isomer of carotin. Tomatoes also contain carotin, a yellow pigment. Lycopin can be extracted from tomato pulp by ether or carbon bisulphide and the crystals obtained by evaporating in vacuo an ether or carbon bisulphide solution of the pigment are dark to light carmine-red in color and of waxy consistency. The crystals when pure melt at 168°C. and possess the empirical formula $C_{40}H_{56}$. Lycopin rapidly oxidizes in contact with air

and fades in color. Preserved in hydrogen, nitrogen or carbon dioxide it retains its color indefinitely.

Dugger[7] states that in the absence of lycopin, the flesh of the tomato is yellow, due to carotin and possibly xanthophyll, which are masked in the red fruit.

Color Changes during Ripening.—According to Hanson[8] the deep green of the chlorophyll first fades to a greenish-white during ripening, which is followed by the development of a yellow or light orange color. Under the microscope yellowish granules and orange crystals can be found in the parenchyma cells at this stage of the ripening process.

As the red color becomes apparent, dark or light carmen-red needle-like or prismatic crystals of lycopin appear. These become grouped in bundles as the color becomes more intense and the yellow pigment decreases in amount.

Effect of Manufacturing Processes on Color.—The quality of tomato products depends to a large degree upon the color, and retention of the natural red color and is one of the most important problems in the manufacture of tomato products.

Chlorophyll, the green pigment of unripe tomatoes, turns brown during cooking, thus greatly reducing the intensity of the natural red color, and if green fruit is used in excessive amounts the color of the product will be brown or brownish-red. Careful sorting will eliminate green fruit.

Tomato products should not be permitted to come in contact with iron, because it causes lycopin to turn brown, and iron salts in catsup and other spiced tomato products combine with tannin from the spices to form iron tannate, a black compound, which may darken the color of the entire contents of the bottle or may form a dark deposit near the surface of the bottled product.

Copper salts also are injurious to tomato color; hence the desirability of using glass-lined equipment.

Prolonged heating causes lycopin to become brown and the cooking and concentrating processes should be accomplished as quickly as possible if a product of bright red color is desired. High temperatures are also harmful to the color. For this reason concentration in vacuo usually yields a product of better color than concentration in an open kettle.

Cooling of the sterilized product should be prompt and thorough. "Stack burning" of insufficiently cooled canned tomatoes has been a frequent cause of poor color.

TOMATO PUREE

Most tomato products are made from tomato puree (often termed tomato pulp), which represents the unflavored, finely divided pulp and juice separated from skins and seeds. It is usually concentrated to a greater or less degree before use in other products or for canning.

Tomato Varieties for Puree.—Tomatoes for puree, catsup, sauce and other tomato products should be of smooth skin, free from wrinkles and folds and should have a shallow stem cavity so that molds and other organisms may not accumulate in such cavities. They should be of deep red color, firm flesh, small seed cavity and should ripen evenly. Size is not as important as in canning because the tomatoes are not peeled (except for chili sauce).

Picking, Transporting and Storing.—Even greater care must be observed in picking, transporting and storing tomatoes for puree, etc., than for canning, because the former are not peeled. Boxes should be washed frequently and not allowed to become moldy. The fields should be picked daily during the height of the ripening season to avoid gathering of unripe and over-ripe tomatoes. They should be transported to the plant without delay in order to avoid mold growth, and for the same reason the tomatoes should be utilized immediately upon arrival at the plant.

The first and probably the most important requisite to success in tomato products manufacture is the use of sound raw material. The manufacturer must be particularly careful in the inspection of deliveries of tomatoes following heavy rains or during prolonged periods of damp weather. Rains cause splitting of the fruit with subsequent rapid development of mold. High "mold counts" are the most frequent cause for rejection or condemnation of tomato products.

Washing.—The tomatoes should be thoroughly washed before sorting, because the work of the sorters is thereby made more effective. Any of the devices described for washing tomatoes for canning may be used but the rotary washer is the most effective.

According to B. J. Howard[1] of the U. S. Department of Agriculture, Bureau of Chemistry, a rotary, heavy wire cylindrical washer inclined at an angle of about 1 foot in 8 and equipped with an abundance of water under heavy pressure should be used. The screen causes the tomatoes to roll, whereas they may merely slide if the cylinder is made of perforated sheet metal. He states that a cylinder 2 to 2½ feet in diameter and 8 feet long and revolving at about 20 revolutions per minute will satisfactorily wash about 2 bushels of tomatoes per minute. Many rotary washers are larger than this and of correspondingly greater capacity.

Simple agitation in water is not satisfactory, because tomatoes often carry, in cracks and in the stem cavity, mold filaments which agitation does not dislodge and which appear later in the finished product where they can be found by the microscope of the food inspector or buyer. Heavy sprays of water will remove a large proportion of such mold filaments and small areas of soft rot not seen by the trimmers and sorters. Sprays more effectively remove adhering clay, dried particles of pulp, etc., from the skins of the tomatoes than does mere agitation in water.

The first requirement of a satisfactory tomato washer is water under heavy pressure (50 to 100 pounds per square inch) driven against the tomatoes in sprays. Agitation during spraying is the second essential.

Efficient and effective washing is one of the most important steps in the manufacture of tomato products and the mold content of the finished article is dependent in a very marked degree upon this operation, because, as was stated above, the tomatoes are not peeled before pulping.*

Sorting.—Howard,[1] who has shown the great importance of careful sorting, makes the following statement:

> A careful consideration of the causes of failure in making clean, sound, sanitary tomato products shows clearly that more difficulty is experienced in effecting sanitary washing, prompt handling and efficient sorting than in any of the other phases of the manufacturing process. Sorting is the most important of these operations, in which judgment of the operator plays an important part. Satisfactory washing is largely a question of proper operation of a mechanical device. This may be said of many of the other operations about the factory, but so far no mechanical device for separating the decayed from the good parts of tomatoes has been placed on the market. This operation must still be performed by hand. In the making of pulp of any kind, efficient sorting is absolutely necessary.

Since sorting is so important, greater care should be exercised in the selection of sorters than in selecting workers for any other operation.

Because of the close attention necessary, this work is very fatiguing, and the workers should be employed in short shifts of not over 3 hours each. Sorting should be in charge of an experienced person who has proved his or her efficiency in this work and who is alert and discriminating as well as able to tactfully direct the other workers.

Sorting Systems.—Various sorting systems are in use. These may be designated as (1) table, (2) simple apron and (3) divided apron.

In using the table system of sorting the tomatoes are dumped upon a stationary table from the box or basket. The badly decayed tomatoes are rejected and small pieces of rot are trimmed from the fruit. The sound tomatoes are placed in suitable containers, such as buckets or pans, and transferred to the washer. The work of individual sorters can be effectively observed and controlled where this system is used, but it is usually more expensive than other methods.

In the simple apron sorting system the tomatoes are carried on a broad and slowly moving belt before the sorters, who remove unfit material and permit the sound fruit to pass over the end of the belt to the washer and pulping machines. Theoretically the tomatoes are subjected to as many sortings as there are workers at the apron and this is practically true if

* The writer is greatly indebted to B. J. Howard of the U. S. Department of Agriculture, Bureau of Chemistry, for much of the material presented on washing and sorting of tomatoes and on plant sanitation.

the speed of the belt is not too great, if the belt is not overloaded, if the sorters are efficient and if the apron is properly lighted. The apron should be narrow enough for the sorters to reach across the entire width, the most convenient width being about 18 to 20 inches.

Fig. 67.—Tomato sorting belt. Note chutes in foreground for rotten fruit and trimmings, and turning device at rear. (*Photograph by B. J. Howard, U. S. Dept. Agr.*)

In the divided apron system the tomatoes are placed upon a conveying apron divided by lengthwise partitions into three alleys. The tomatoes are carried in the two outside sections. The sorters place the sound fruit in the central section and allow the unfit material to pass over the end of the belt through the outside sections. In some cases the rotten fruit is placed on the central conveyor and the sound fruit in the outside sections. Practically every tomato must be handled and, although an effective method of sorting, it is more expensive to operate than the simple apron.

Proportion of Moldy Fruit to be Removed.—Howard,[1] in reporting the results of 100 tests in 30 factories east of the Mississippi River, states that the proportion of moldy tomatoes (wholly or in part) in unsorted fruit varied from 0.4 per cent to 81 per cent and that the average was about 25 per cent. This means that about 58 tomatoes must be removed or trimmed from each bushel.

Rate of Movement of Apron.—The speed of the apron should be slow enough for the sorters to recognize and remove or trim all tomatoes containing rot and should not exceed 25 feet per minute. Howard reports speeds of from 16 to 140 feet per minute in various factories.

Volume of Fruit Sorted.—A bushel of tomatoes (about 60 pounds) covers, according to Howard,[1] from 7 to 12½ square feet and an average of about 9⅓ square feet. Experience has shown that not more than one-half of the area of the belt should be covered in order to permit effective sorting. Therefore, a space of at least 18½ square feet should

be allowed for each bushel in designing the sorting belt for a given plant. A belt 18 inches wide and moving at a rate of 25 feet per minute would have, on this basis, a capacity of about 120 bushels per hour, or 1,200 bushels (36 tons) per 10 hours, and would require the services of six sorters.

Under average conditions of table sorting one sorter can care for 5 to 8 bushels (about 300 to 500 pounds) per hour, and in apron sorting, 20 to 25 bushels per hour. A rate of 25 bushels per hour should be considered the maximum for efficient sorting.

The tomatoes should be fed to the sorting belt at a uniform rate of speed. The custom, observed in some factories, of dumping several boxes of tomatoes on the apron at irregular intervals causes the belt to be overloaded for short periods and empty during the interval between dumpings. Fairly satisfactory feeding hoppers are now obtainable and should be used to regulate the rate of flow of tomatoes to the apron. The tomatoes should not be heaped on the belt, but should be only one layer deep and not crowded tightly together.

Turning.—In many factories the sorting aprons are equipped with turning devices which automatically turn the tomatoes so that all portions of the surface of the fruit can be inspected by the sorters. One form of turning device consists of several pieces of water pipe, ¾ to 1 inch, about 7 inches long, suspended from a steel rod above the sorting apron. The pipes are free to swing in the direction of flow of the apron. As the tomatoes pass beneath the pieces of pipe, the weight of the latter is sufficient to turn the fruit.

Howard has found that not more than 50 per cent of the area of the apron should be covered with tomatoes in order to give space for the tomatoes to be turned properly. On rubber or canvas belts there is a tendency for the tomatoes to slip instead of to turn and the turning device operates more satisfactorily on woven metal conveyors (see Fig. 67).

Importance of Proper Lighting.—The speed and efficiency of sorting depend to a marked degree upon the lighting of the sorting belt. Effective sorting cannot be done if the sorting apron is located in a poorly lighted corner of the factory or if artificial light is not used on foggy or cloudy days. The lights should be directly above the sorting belt and so placed that the shadows of the workers do not fall upon the fruit.

Effect on Quality of Sorting.—Howard[1] has found the percentage of rotten material in tomatoes delivered to a large number of plants under his observation has varied from practically 0 to over 30 per cent, and that the average was about 5.5 per cent. The percentage of rot in the sorted product varied from practically 0 to over 7 per cent, with an average of about 1⅓ per cent. By careful sorting, material should be considerably below this average and at no time should it exceed 1 per cent.

The proportion of rot is determined by weighing samples of 20 to 50 pounds of the sorted tomatoes direct from the belt and by trimming out and weighing objectionable portions.

Trimming.—Many of the tomatoes removed by the sorters can be trimmed and the sound portions of the fruit salvaged.

The canner, however, must not be too zealous in his attempt to salvage by trimming, or he may badly damage the quality of his finished product. Enough of the tomato must be cut away to insure complete removal of rot and flesh which has absorbed a disagreeable flavor from the adjacent rot.

Use of Peels and Cores.—If tomatoes used in canning are very carefully sorted and trimmed before scalding, the cores and peels may be used for the preparation of puree, but the sorting to be effective must be done before scalding and cannot be done satisfactorily by the peelers.

Attempts have been made to wash the rot from peels and cores from unsorted fruit, but besides being very ineffective this results in great loss of tomato juice and pulp.

It is impossible to sort out rotten material from peels and cores and, furthermore, such an attempt contaminates the whole mass of material with soft rot from badly decayed portions.

Pure Food and Drug officials state that in the majority of cases brought in the past against tomato products, the goods involved were made from trimmings (*i.e.*, peels and cores).

Howard[1] recommends not less than one-eighth as many sorters and trimmers as peelers, if peels and cores are to be used for tomato products.

Pulping.—The sorted and trimmed tomatoes are converted into pulp by means of a specially constructed machine commonly known as a "cyclone" or pulper. The machine usually consists of a heavy copper, brass or bronze perforated sheet or screen in the form of a half cylinder which forms the lower half of the cylinder of the pulping machine. The upper half of the cylinder is of wood or heavy sheet copper. Heavy paddles revolve at a high rate of speed within the cylinder and the tomatoes are broken by impact of the paddles or by being thrown against the walls of the pulper. The pulp and juice pass through the screen into a tank, and the skins, seeds and fiber pass out through an opening at the lower end of the pulper. The tomatoes enter the pulping cylinder through a hopper, usually fed by a continuous conveyor and the mixture of pulp and juice is pumped to the concentrating kettles or other equipment (see Fig. 68).

Recently there has been developed a centrifugal pulping machine which consists of an upright cylindrical screen against which the tomatoes are thrown violently by centrifugal force. Large capacity and efficient operation are claimed for this device.

Heating.—In most factories the present custom is to convey the washed, sorted and trimmed tomatoes direct to the pulper without preliminary heating. In one system of hot pulping the whole tomatoes are conveyed to a "breaking tank" and cooked with steam coils until thoroughly heated and softened. In some plants the tomatoes are crushed before heating and the hot fruit is then pulped in the usual manner. This method gives a somewhat higher yield of pulp than is

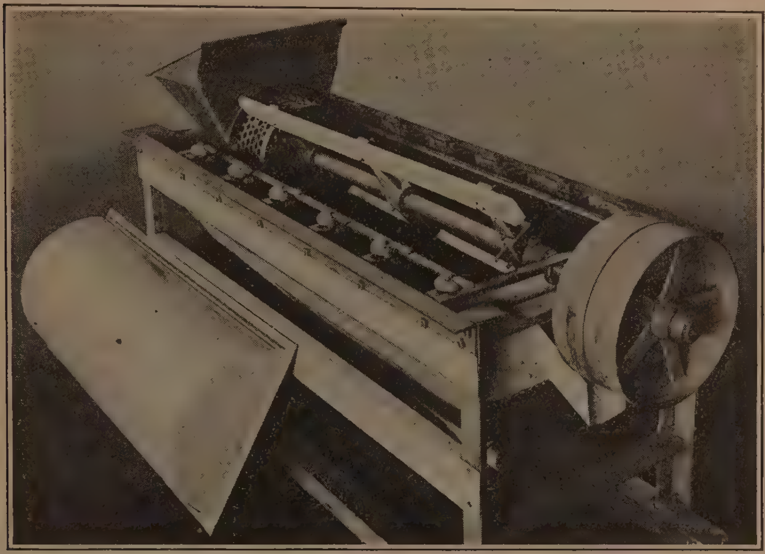

FIG. 68.—Tomato pulper. Top removed to show paddles and screen. (*Courtesy, Anderson Barngrover Co.*)

obtained by cold pulping and a pulp richer in pectin and gums, which increases the viscosity and decreases the tendency for the pulp and juice to separate. Catsup from hot pulped tomatoes will "stand up" and not spread when a drop of the catsup is placed upon a blotter, in sharp contrast to that from cold pulped tomatoes, which flattens and spreads quickly in the "blotter test."

It is doubtful whether hot pulping improves the color of the pulp, but it kills microorganisms and eliminates any increase in their number during normal operation of the plant.

Conveying Pulp to Concentrator.—Pumps should be made of bronze or other metal not acted upon to any marked degree by the acid of the tomatoes. Iron and steel become rusty and dissolve in the tomato juice to a sufficient extent to cause darkening of the color.

Pipes through which the pulp is conveyed should also be of material which does not injure the quality of the product. Glass-lined (enamel-lined) iron pipes are resistant to tomato acid and are easily cleaned. Block

tin pipes or silver-lined copper pipes have been successfully used. Wooden pipes have been used quite extensively but are difficult to clean and usually permit development of mold and bacteria during periods of idleness, with subsequent serious contamination of the pulp with these organisms.

Pipe lines should be cleaned thoroughly at the end of the day by flushing with water and by steaming. Before use in the morning, water

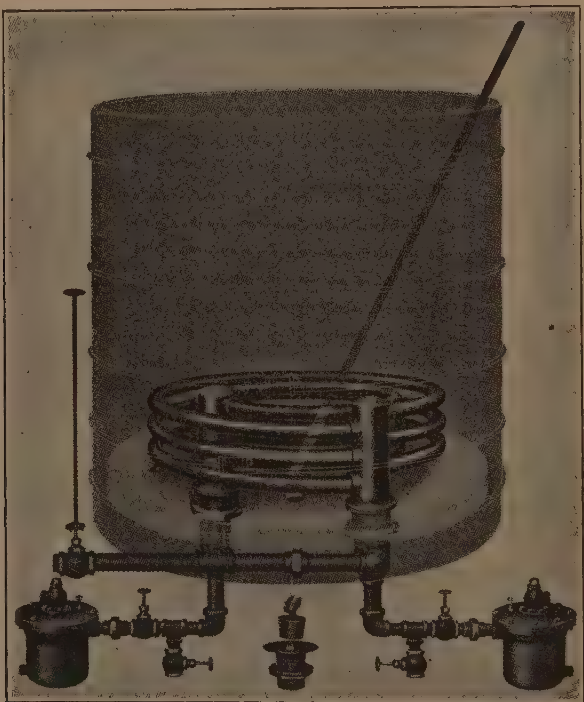

FIG. 69.—"Kookmor" flash coil for the concentration of tomato pulp. (*Courtesy, Anderson Barngrover Co.*)

should be pumped through them. Pipe lines are often prolific sources of infection if not cleaned frequently and thoroughly. Joints should be smooth and not permit of accumulation of pulp and growth of mold.

Concentration of the Pulp.—The raw pulp is too thin to be used without concentration and must be evaporated to the desired consistency before canning or using for tomato catsup or other tomato products.

Open Cookers.—Open kettles used for concentrating tomato pulp are made of wood, copper, tin-lined copper or of glass-lined steel. The last named material is readily cleaned and is becoming the most popular type of construction.

Open kettles are often not steam jacketed but are heated by closed copper coils known as flash coils. The diameter of the usual flash coil is about 3 inches. This relatively large diameter gives a large heating surface, allows free passage of the steam and rapid and uniform heating of the coils, so that local overheating and sticking of the pulp are reduced to a minimum (see Fig. 69). Such a coil will under normal conditions reduce a charge of 500 gallons of pulp to one-half its original volume in 35 to 45 minutes, or less.

Wooden Tanks.—Cypress is most commonly used for wooden concentrators, but wooden tanks are apt to impart a musty or moldy flavor to the pulp unless kept clean and free from mold growth when not in use.

Copper Kettles.—Copper kettles are more expensive than wooden tanks or glass tanks equipped with flash coils and have the additional objection that the copper may injure the tomato color.

Glass-lined Kettles.—So-called glass-lined tanks are constructed of an outer shell of steel lined on the inside with heavy enamel, which is fused into the steel at a high temperature. The surface is smooth and easily washed and the enamel is practically insoluble in the juice, and for these reasons this equipment is rapidly displacing wood and copper. A common size for such tanks is about 1,100 gallons, a convenient size for a 600-gallon batch of pulp.

Vacuum Pans.—Vacuum kettles are used in some plants, their principal advantage being in reduction of the boiling point to 160°F. or less, making it possible to retain the color and flavor of the tomatoes to a remarkable degree. They are, however, expensive in construction, require expensive vacuum pumps, large amounts of water for condensation of the vapors evolved in boiling and require more expert knowledge and skill for operation than do open kettles. The construction and operation of vacuum pans will be found discussed at greater length in Chapter XVI.

Cooking the Pulp.—In order to prevent foaming and sticking of the pulp to the coils, some manufacturers of pulp add a small amount of cottonseed oil to the kettle, so that as the pulp rises during the filling of the kettle, the sides and coils are coated with oil. Foaming can, however, be avoided by careful heating and by spraying the surface with water.

As soon as the coil or steam jacket is covered, steam may be admitted and boiling started. During the first stages of boiling the coil or jacket must be well drained to prevent its filling with water, a condition which favors scorching.

Concentration must be accomplished rapidly in order to retain the bright red tomato color and fresh flavor. A boiling of 30 minutes is usually sufficient in a tank equipped with a good flash coil and an adequate supply of steam under high pressure.

Determining the Finishing Point.—Manufacturers of tomato pulp (puree) experience considerable difficulty in obtaining a finished product of uniform composition, and in determining accurately the point at which to stop the boiling process.

The pulp is usually concentrated to and sold upon a definite specific gravity, which is usually 1.035 or 1.04.

Concentrating to Definite Volume.—The boiling process is very short and it is very difficult during boiling to make a determination of specific gravity which may be used to establish the end point of the boiling process accurately. Bigelow[9] and Fitzgerald, therefore, recommend concentration of a measured volume of the raw pulp to a definite volume of concentrated puree. In boiling tanks with straight sides the volume may be determined by a measuring stick, due allowance being made for the volume occupied by the heating coil. A more accurate method is to calibrate the tank by adding measured volumes of water. The specific gravity and temperature of the raw pulp from the pulping machines are determined accurately. From these data and Table 49 the volume to which the pulp must be concentrated is determined.

If, for example, 100 gallons of raw pulp of specific gravity of 1.022 is measured into the kettle and the volume to which this pulp must be concentrated to reach a gravity of 1.035 is desired, it will be found by consulting Table 49 in the column headed "100 parts unconcentrated pulp at 86°F." and opposite 1.022, that the final volume should be, at 212°F., 69.3 gallons. If the batch is 500 gallons, then the final volume will be $5 \times 69.3 = 356.5$ gallons.

If the operator desires to know how many gallons of raw pulp must be used to produce 100 gallons of finished concentrated pulp of 1.035, he would use Table 50. Thus for raw pulp of specific gravity of 1.022, 158 gallons will be required to yield 100 gallons of pulp of 1.035 gravity, and to produce 500 gallons of the concentrated pulp, $5 \times 158 = 790$ gallons of raw pulp would be required.

By Specific Gravity.—In some factories the specific gravity of the pulp during the boiling process is determined and the end point estimated on this basis. However, such rapidly made determinations are liable to be very inaccurate, for reasons noted below, or if done accurately they cannot be made quickly enough to be of very great value to the operator of the kettle.

Other manufacturers merely concentrate until they feel certain that the product complies with the specifications and base their judgment entirely on the appearance and feel of the product. Such a "hit or miss" method is certain to be extremely unreliable, not only because of the human equation but also because of the variation in the texture and appearance of pulps of the same specific gravity, and because of the similarity of appearance and texture of pulps of different specific gravities. If con-

centrated too far, specifications will be exceeded and a low yield obtained; if not concentrated sufficiently, the producer will be penalized by the purchaser. Therefore, accurate control of specific gravity is essential.

In addition to measuring the raw and concentrated pulps, the manufacturer must make accurate determinations of the specific gravity of each finished lot of pulp in order that he may know whether it is of the desired density.

TABLE 49.—VOLUME OF TOMATO PULP AT 212°F. RESULTING FROM THE EVAPORATION OF 100 PARTS OF UNCONCENTRATED PULP

Specific gravity of concentrated pulp at 68°F., 1.035
(*After Bigelow and Fitzgerald*)

Specific gravity of concentrated pulp at 68°F.	Volume at 212°F. of pulp of specific gravity 1.035 at 68°F.							
	100 parts unconcentrated pulp at 68°F.	100 parts unconcentrated pulp at 77°F.	100 parts unconcentrated pulp at 86°F.	100 parts unconcentrated pulp at 95°F.	100 parts unconcentrated pulp at 104°F.	100 parts unconcentrated pulp at 122°F.	100 parts unconcentrated pulp at 140°F.	100 parts unconcentrated pulp at 158°F.
1.0170	47.9	47.8	47.7	47.7	47.6	47.4	47.1	46.9
1.0175	49.5	49.4	49.3	49.3	49.2	49.0	48.7	48.5
1.0180	51.1	51.0	50.9	50.9	50.8	50.6	50.3	50.1
1.0185	52.6	52.5	52.4	52.4	52.3	52.0	51.8	51.5
1.0190	54.2	54.1	54.0	54.0	53.9	53.6	53.4	53.1
1.0195	55.8	55.7	55.7	55.6	55.5	55.2	55.0	54.7
1.0200	57.3	57.3	57.2	57.1	57.0	56.7	56.5	56.1
1.0205	58.9	58.8	58.8	58.7	58.6	58.3	58.1	57.7
1.0210	60.4	60.3	60.3	60.2	60.1	59.8	59.5	59.2
1.0215	61.9	61.9	61.8	61.7	61.6	61.3	61.0	60.7
1.0220	63.4	63.3	63.3	63.2	63.0	62.7	62.5	62.2
1.0225	65.0	65.0	64.9	64.8	64.7	64.4	64.1	63.8
1.0230	66.7	66.6	66.5	66.4	66.3	66.0	65.7	65.3
1.0235	68.2	68.1	68.0	67.9	67.8	67.5	67.2	66.8
1.0240	69.7	69.6	69.5	69.4	69.3	69.0	68.7	68.3
1.0245	71.3	71.2	71.1	71.0	70.9	70.6	70.3	69.9
1.0250	72.8	72.7	72.6	72.5	72.3	72.1	71.8	71.4
1.0255	74.3	74.3	74.2	74.0	73.9	73.6	73.3	72.9
1.0260	75.9	75.8	75.7	75.5	75.4	75.1	74.8	74.3
1.0265	77.4	77.3	77.2	77.1	76.9	76.6	76.3	75.8
1.0270	78.9	78.8	78.7	78.6	78.4	78.1	77.7	77.3
1.0275	80.5	80.4	80.3	80.2	80.1	79.7	79.4	78.9
1.0280	82.0	81.9	81.8	81.7	81.6	81.2	80.9	80.4
1.0285	83.6	83.5	83.4	83.2	83.1	82.8	82.4	81.9
1.0290	85.2	85.1	85.0	84.9	84.7	84.4	84.0	83.5

Table 51 gives the factor necessary to correct the specific gravity of pulp determined at other temperatures than 68°F.

TABLE 50.—VOLUME OF UNCONCENTRATED PULP REQUIRED TO PRODUCE 100 PARTS OF TOMATO PULP AT 212°F.

Specific gravity of concentrated pulp at 68°F., 1.035

(*After Bigelow and Fitzgerald*)

Specific gravity of unconcentrated pulp at 68°F.	Volume of unconcentrated pulp at designated temperature required to produce 100 parts of tomato pulp of s.g. 1.035							
	68°F.	77°F.	86°F.	95°F.	104°F.	122°F.	140°F.	158°F.
1.0170	208.8	209.2	209.6	209.6	210.1	211.0	212.3	213.2
1.0175	202.0	202.4	202.8	202.8	203.3	204.1	205.3	206.2
1.0180	195.7	196.1	196.5	196.5	196.9	197.6	198.8	199.6
1.0185	190.1	190.5	190.8	190.8	191.2	192.3	193.1	194.2
1.0190	184.5	184.8	185.2	185.2	185.5	186.6	187.3	188.3
1.0195	179.2	179.5	179.5	179.9	180.2	181.2	181.8	182.8
1.0200	174.5	174.5	174.8	175.1	175.4	176.4	177.0	178.3
1.0205	169.8	170.1	170.1	170.4	170.6	171.5	172.1	173.3
1.0210	165.6	165.8	165.8	166.1	166.4	167.2	168.1	168.9
1.0215	161.6	161.6	161.8	162.1	162.3	163.1	163.9	164.7
1.0220	157.7	158.0	158.0	158.2	158.7	159.5	160.0	160.8
1.0225	153.8	153.8	154.1	154.3	154.6	155.3	156.0	156.7
1.0230	149.9	150.2	150.4	150.6	150.8	151.5	152.2	153.1
1.0235	146.6	146.8	147.1	147.3	147.5	148.1	148.8	149.7
1.0240	143.5	143.7	143.9	144.1	144.3	144.9	145.6	146.4
1.0245	140.3	140.4	140.6	140.8	141.0	141.6	142.2	143.1
1.0250	137.4	137.6	137.7	137.9	138.3	138.7	139.3	140.1
1.0255	134.6	134.6	134.8	135.1	135.3	135.9	136.4	137.2
1.0260	131.8	131.9	132.1	132.5	132.6	133.2	133.7	134.6
1.0265	129.2	129.4	129.5	129.7	130.0	130.5	131.1	131.9
1.0270	126.7	126.9	127.1	127.2	127.6	128.0	128.7	129.4
1.0275	124.2	124.4	124.5	124.7	124.8	125.5	125.9	126.7
1.0280	122.0	122.1	122.2	122.4	122.5	123.2	123.6	124.4
1.0285	119.6	119.8	119.9	120.2	120.3	120.8	121.4	122.1
1.0290	117.4	117.5	117.6	117.8	118.1	118.5	119.0	119.8

TABLE 51.—CORRECTIONS FOR THE SPECIFIC GRAVITY OF TOMATO PULP AT VARIOUS TEMPERATURES TO 68°F.

To be subtracted from observed specific gravity
(*After Bigelow and Fitzgerald*)

Temperature		Correction factor	Temperature		Correction factor	Temperature		Correction factor
Degrees F.	Degrees C.		Degrees F.	Degrees C.		Degrees F.	Degrees C.	
50	10.0	0.0016	56	13.3	0.0011	62	16.7	0.0007
51	10.6	0.0015	57	13.9	0.0010	63	17.2	0.0005
52	11.1	0.0015	58	14.4	0.0009	64	17.8	0.0004
53	11.7	0.0014	59	15.0	0.0009	65	18.3	0.0003
54	12.2	0.0013	60	15.6	0.0008	66	18.9	0.0002
55	12.8	0.0012	61	16.1	0.0008	67	19.4	0.0001
To be added to observed specific gravity								
69	20.6	0.0001	75	23.9	0.0009	81	27.2	0.0017
70	21.1	0.0002	76	24.4	0.0010	82	27.8	0.0018
71	21.7	0.0003	77	25.0	0.0011	83	28.3	0.0020
72	22.2	0.0004	78	25.6	0.0012	84	28.9	0.0021
73	22.8	0.0006	79	26.1	0.0014	85	29.4	0.0023
74	23.3	0.0007	80	26.7	0.0015	86	30.0	0.0025

Concentration by Draining Off of Juice.—At one time it was common practice to place the freshly prepared raw pulp in settling tanks, in which the insoluble solids rose to the surface and the juice separated in a clear layer in the bottom of the tank. This juice (termed "water" by the canner) was drawn off and discarded and only the upper portion containing the solids was used. Bigelow has shown that the juice is just as rich in dissolved solids as the pulp itself and that discarding it results in very serious lowering of yield and in injury to quality.

Specific Gravity Methods.—Several methods are in use in tomato products factories for the determination of specific gravity. The more important are given below.

Sprague Cup Method.—The most common method of determining the specific gravity of tomato pulp is by use of the Sprague cup and balance. The cup is a conical copper vessel holding 1 liter. This is filled level full with boiling water, the outside is dried carefully and the cup with contents is weighed. It is again weighed level full of the boiling hot pulp. The scale is so constructed that the weight of the empty cup is counterpoised and the ratio of weight of the pulp to that of the water gives the specific gravity of the pulp.

In filling the cup the pulp cools somewhat, which will cause its specific gravity to increase. Air may be trapped in the pulp and cause it to weigh less than it should. Although these are compensating errors, one or the other frequently causes very serious inaccuracies in the determination. Bigelow and Fitzgerald[11] have found that very much more reliable results are obtained by immersing the cup in the hot pulp in the boiling tank and leveling off the surface of the pulp at once. This reduces to a minimum both the errors noted above. The principal merits of the method are rapidity and simplicity.

In determining the specific gravity of cold pulp, this same apparatus may be used. Here, however, entrapped air becomes a very serious source of errors and the cup and contents must be centrifuged several minutes to expel air, before the weighing is made.

Pycnometers.—Special heavy walled small bottles or pycnometers, weighed on an analytical balance, are now used by many chemists in preference to the metal cup described above. (For use of pycnometers for tomato products, see Cruess' and Christie's "Laboratory Manual.")

By Hydrometer.—Because of the thick consistency of tomato pulp, it is difficult to obtain accurate hydrometer readings on the unfiltered pulp. Nevertheless Hier[1] states that he finds the hydrometer very good for plant control purposes.

Bigelow and Fitzgerald[11] have found that the juice from the hot pulp may be quickly filtered through a cheesecloth to give a clear filtrate practically free from suspended solids. The specific gravity of the filtrate can then be determined with speed and accuracy. The temperature also is taken and suitable correction made, or the filtrate is chilled in the cylinder by packing it in crushed ice and the reading is taken at the standard temperature of 20°C. (68°F.) They have established the relation between the hydrometer reading so obtained, the specific gravity of the unfiltered pulp and the total solids by drying to constant weight in vacuo at 70°C. (158°F.) as shown in Table 52.

Canners report that the method developed by Bigelow and Fitzgerald gives good results in practice, and is rapid and dependable, although it is recommended that the hydrometers used be checked each season against a standard method such as the pycnometer method. This is desirable because of the personal factor involved, the variation in hydrometers, variation in method of preparing pulp and variation in the composition of the tomatoes themselves.

By Weight of Dried Sample.—As indicated in Table 52, there is a definite relation between specific gravity and total solids determined by drying at 70°C. in vacuo. When dried in an oven at atmospheric pressure, tomato products decompose rather rapidly and results for moisture so obtained will be too high.

TABLE 52.—RELATION BETWEEN TOTAL SOLIDS AND SPECIFIC GRAVITY OF TOMATO PULP AND FILTRATE

(*After Bigelow and Fitzgerald*)

Per cent solids in pulp	Specific gravity at 20°C.		Per cent solids in pulp	Specific gravity at 20°C.		Per cent solids in pulp	Specific gravity at 20°C.	
	Pulp	Filtrate		Pulp	Filtrate		Pulp	Filtrate
3.42	1.0150	1.0133	7.06	1.0297	1.0274	10.41	1.0433	1.0404
3.53	1.0155	1.0138	7.17	1.0301	1.0279	10.52	1.0437	1.0409
3.64	1.0159	1.0142	7.28	1.0306	1.0283	10.64	1.0442	1.0413
3.76	1.0163	1.0146	7.34	1.0308	1.0285	10.70	1.0444	1.0415
3.87	1.0168	1.0151	7.45	1.0313	1.0290	10.80	1.0449	1.0419
3.98	1.0172	1.0155	7.56	1.0317	1.0294	10.91	1.0453	1.0424
4.09	1.0177	1.0160	7.62	1.0320	1.0296	10.97	1.0456	1.0426
4.20	1.0181	1.0164	7.74	1.0324	1.0300	11.08	1.0461	1.0430
4.26	1.0183	1.0166	7.85	1.0329	1.0305	11.20	1.0465	1.0435
4.37	1.0188	1.0170	7.90	1.0331	1.0307	11.25	1.0467	1.0437
4.48	1.0192	1.0175	8.02	1.0336	1.0311	11.36	1.0472	1.0441
4.59	1.0197	1.0179	8.12	1.0340	1.0315	11.47	1.0476	1.0446
4.71	1.0201	1.0183	8.24	1.0345	1.0320	11.59	1.0481	1.0450
4.82	1.0205	1.0188	8.35	1.0349	1.0324	11.70	1.0485	1.0454
4.93	1.0210	1.0192	8.46	1.0354	1.0328	11.81	1.0490	1.0459
5.03	1.0215	1.0196	8.57	1.0358	1.0333	11.93	1.0494	1.0463
5.10	1.0217	1.0198	8.68	1.0363	1.0337	12.05	1.0499	1.0467
5.21	1.0222	1.0203	8.74	1.0365	1.0339	12.10	1.0501	1.0469
5.33	1.0226	1.0207	8.86	1.0370	1.0344	12.21	1.0505	1.0474
5.44	1.0230	1.0211	8.96	1.0374	1.0348	12.32	1.0510	1.0478
5.55	1.0235	1.0216	9.14	1.0381	1.0354	12.43	1.0515	1.0482
5.66	1.0240	1.0220	9.25	1.0386	1.0359	12.55	1.0519	1.0487
5.77	1.0244	1.0225	9.36	1.0390	1.0363	12.65	1.0524	1.0491
5.88	1.0249	1.0229	9.47	1.0395	1.0368	12.77	1.0528	1.0495
5.94	1.0251	1.0231	9.58	1.0400	1.0372	12.88	1.0533	1.0500
6.05	1.0256	1.0235	9.70	1.0404	1.0376	12.99	1.0538	1.0504
6.16	1.0260	1.0240	9.80	1.0408	1.0381	13.10	1.0542	1.0508
6.22	1.0263	1.0242	9.92	1.0413	1.0385	13.22	1.0547	1.0513
6.33	1.0267	1.0246	10.02	1.0417	1.0389	13.32	1.0551	1.0517
6.45	1.0272	1.0251	10.14	1.0421	1.0394	13.44	1.0556	1.0521
6.50	1.0274	1.0253	10.25	1.0426	1.0398	13.55	1.0560	1.0525
6.61	1.0279	1.0257	10.35	1.0430	1.0402	13.66	1.0565	1.0529
6.72	1.0283	1.0261	.....	......	......	13.78	1.0569	1.0533
6.84	1.0288	1.0266	.....	......	......	13.89	1.0574	1.0537
6.95	1.0292	1.0270	.....	......	......	14.01	1.0579	1.0241

The official method for this determination is as follows:

Place from 2 to 4 grams of the well-mixed sample in an accurately weighed flat-bottomed dish about 2½ inches in diameter, spreading thinly. Accurately

weigh dish and sample. Place in a vacuum and dry at 70°C. and 28 to 29 inches vacuum (inches of mercury) for 4 hours. Remove and weigh immediately.

In the absence of a vacuum oven 10 grams of the sample is evaporated to dryness in a broad shallow dish over a steam bath. It is then dried in an oven at 95 to 100°C. (203 to 212°F.) for 4 hours and weighed. The per cent of solids thus obtained is multiplied by 1.085 to give the true percentage. This method is not so accurate as drying in vacuo, but will serve for factory control.

Finishing.—Tomato puree should be smooth in texture and fine-grained. The pulping machine allows relatively large pieces of pulp and some fiber to pass through the screens and cooking coagulates or granulates the pulp more or less. It is, therefore, customary, before canning the puree, to pass it through a finisher to improve the texture.

A finisher consists of a horizontal cylinder or a vertical cone made of a fine sieve of bronze or monel metal, inside of which are heavy bristle brushes which revolve rapidly, causing the fine pulp to pass through the screen and the pieces of skin, seeds, fiber, etc., to pass out the end of the machine.

Canning and Sterilizing.—If for household use, the puree should be canned in No. 1 or No. 2 cans; if for sale to large users, it is canned in No. 10 or in 5-gallon cans.

The No. 10 and smaller cans are usually filled by a rotary automatic filler at 170 to 185°F. and sealed hot, generally no exhaust being necessary. The filled cans are sterilized usually in agitating cookers at 212°F., about 25 to 30 minutes for No. 10 and about 15 minutes for No. 1 cans.

The 5-gallon cans are filled boiling or scalding hot (180°F. or above) and are sealed at once with a soldering steel and cap. Most packers do not process the filled cans but rely upon the temperature of the hot pulp for sterilization. The 5-gallon cans are made of very heavy tin plate and with care can be used several seasons, provided the cans are rinsed thoroughly with hot water after opening and are dried at once to prevent rusting. These cans, particularly filled cans, must be handled carefully to avoid development of leaks.

At one time 50-gallon barrels were used generally for pulp, sodium benzoate or distilled vinegar being used as preservatives, or the barrels were filled hot and sealed without addition of preservatives. This practice is now seldom followed because of the frequent growth of mold and bacteria in the barrels with consequent frequent and costly condemnation by Pure Food officials.

Lot Records.—The canner should stack each lot of pulp separately and give it a number or other mark of identification in order that goods below standard may be segregated from the better grades. A complete record of each lot should be kept, the record to contain data on quality, treatment of raw material, specific gravity, microscopical examination,

with notes on any deviations from the usual procedure. Records of this type are very valuable in locating causes of trouble in the plant.

Cooling.—Tomato puree is a poor conductor of heat and if stacked hot is very apt to develop a brown color and scorched flavor through "stack burning." The cans should be promptly and thoroughly cooled after processing.

TOMATO PASTE

Tomato paste is a staple article of diet in Italy where it is used very generally under the name of "Salsa di Pomodoro" as a flavoring for many Italian dishes. It is a pasty, semi-solid product of about the consistency of heavy apple butter and present standards require it to contain at least 20 per cent total solids when dried to constant weight in vacuo at 70°C. Concentrated tomato paste must contain at least 30 per cent total solids as determined by drying in vacuo at 70°C. Being highly concentrated, tomato paste is economical in its use of space and is not costly to transport.

In one large tomato paste factory in California the pulp is concentrated to a heavy consistency in vacuum pans. The hot pulp is then transferred to an open jacketed kettle equipped with a revolving stirring and scraping device and concentrated to the desired final density. It is filled into 6-ounce cans and sealed hot. Usually no sterilization is required, unless the paste has cooled considerably before filling.

The concentration is normally about 8:1, but varies from about 7:1 to 10:1 by volume.

One European method consists in storing the raw pulp in tanks or barrels several days to allow fermentation to occur. The pulp rises to the surface and the "water" is discarded. The pulp is drained in bags and is then mixed with a small amount of salt and spread in the sun to dry sufficiently to check molding. Olive oil and garlic may be added.

In another method observed by the writer and in use in a small California factory, the pulp was boiled to a pasty consistency in a vacuum pan. The product was then dried in the sun on fruit trays. A similar method, according to Howard, is used in Italy.

The last two methods yield products high in counts of microorganisms and will not usually pass the Pure Food standards.

TOMATO CATSUP

Tomato catsup is the most popular condiment used in the United States and a very large quantity of tomatoes is used in its manufacture.

Raw Materials.—In some cases the catsup is made direct from the raw pulp; in others the pulp is produced, concentrated and canned in various tomato districts and is shipped to large catsup plants for conversion into finished catsup.

In any case, only clean wholesome tomatoes of intense red color, and of meaty, not watery, texture should be used. High acidity and a rich tomato flavor are additional desirable qualities.

Preparation of the Pulp.—The principles of preparing puree apply with equal or greater force to the preparation of pulp for catsup. Catsup is a more highly concentrated product than the average puree and microorganism counts are thereby increased more or less proportionately, a factor which must be taken into consideration in selecting, sorting, washing and otherwise preparing the pulp for catsup.

The tomatoes are in most factories pulped cold, but it has been proved that boiling the tomatoes before pulping extracts pectin from the seed coats and skins, causing the catsup to be of thicker consistency and to respond favorably to the "blotter" test.

In some factories the pulp is concentrated to a specific gravity of about 1.058 to 1.06 before use in catsup; in others the raw fresh pulp or pulp of 1.035 or 1.04 specific gravity is employed.

Spices and Condiments.—Catsup contains various spices in addition to sugar, salt and vinegar and the character of commercial catsups varies largely according to the kinds and proportions of spices used.

Cloves should be of the headless type, because the clove heads carry a large amount of tannin, which dissolves in the catsup or vinegar and may combine with iron salts to cause darkening. Penang cloves are most popular.

Cinnamon is used in broken stick form, Saigon cinnamon being usually recommended. Mace from Penang or Banda is usually specified in preference to that from other districts.

Cayenne and onions are desired for their pungency rather than for other qualities. Hot onions are preferred to mild ones, the same being true of cayenne.

Distilled vinegar, rather than cider vinegar, is used for catsup because a strong vinegar (of 10 per cent acetic acid) is desired. If cider vinegar were used it would be necessary to concentrate the catsup considerably to expel its excess water.

Salt and sugar should be of high quality.

Paprika is sometimes added to intensify the red color of the catsup but adds very little to the flavor.

Extraction of Spices.—Spices are usually added as a vinegar extract of the whole or coarsely broken spices, prepared by adding the spices to distilled vinegar and steeping at or near the boiling point in a covered wooden or glass-lined tank for 2 or 3 hours. The vinegar is then separated from the spices and is added to the pulp in the catsup kettle.

In some factories the onions, garlic and spices are tied in bags, and hung in the boiling catsup for extraction of flavors and essential oils.

The spices retain some oil after the boiling process and can be used a second time if fresh spices are also added. Campbell[12] gives the following analyses of cinnamon and cloves before and after such boiling:

TABLE 53.—ANALYSES OF CINNAMON AND CLOVES BEFORE AND AFTER EXTRACTING (*After Campbell*)

	Cinnamon		Cloves	
	Before boiling, per cent	After boiling, per cent	Before boiling, per cent	After boiling, per cent
Total ether extract	7.20	3.80	30.50	14.40
Fixed oil	3.90	2.65	12.55	8.00
Volatile oil	3.30	1.15	17.95	6.40
Ash	5.75	2.55	5.80	5.75

Powdered spices have been added direct to the pulp for flavoring purposes, but these impart a dark color. The method, while satisfactory for home use, is unsuited to commercial practice.

Essential oils of cloves and other spices have been successfully used. Oil extracts and acetic acid extracts of spices may also be used.

Oleo resins, which are proprietary preparations consisting of concentrated volatile solvent extracts of spices in the form of resins or syrupy extracts, are sometimes used. These contain flavors and aromas in addition to those of the essential oils and should be superior for this reason to the latter for flavoring purposes. The resins are mixed with a sugar syrup before adding to the catsup.

Formulas.—A number of satisfactory formulas, of which the following is typical, are in commercial use

Heavy puree	100 gallons (specific gravity 1.06)
Salt	28 pounds
Sugar	125 pounds
Chopped onions	25 pounds
Cinnamon (broken bark)	25 ounces
Mace	3½ ounces
Whole cloves (headless)	15 ounces
Allspice	15 ounces
Cayenne	3½ ounces
Chopped garlic (optional)	4 ounces
Vinegar (distilled, of 10 per cent acetic acid)	12 gallons
Paprika (ground, optional)	2 pounds

The spices (except paprika, onions and garlic) are placed in the vinegar and cooked in a covered kettle about 2 hours at the simmering point, and the sugar and salt may then be dissolved in the vinegar. The

extract thus obtained, freed of the solid spices, is added to the catsup near the end of the boiling process. The paprika is added in powdered form direct to the catsup, if the manufacturer desires to use it. The above formula makes slightly more than 100 gallons of catsup.

If desired, the spices may be boiled in a bag with the puree and the chopped onions and garlic added direct to the tomato pulp. They can be separated from the catsup, after cooking, by means of a finisher.

Cooking.—The puree is boiled with the spices, salt and sugar in order to concentrate the product to the desired consistency and to blend the various ingredients. The cooking is usually done in an open glass-lined tank equipped with a flash coil, although a vacuum pan, steam-jacketed copper kettle or a wooden tank and copper flash coil may be used. As is the case with puree, a product of brighter color is obtained by cooking in vacuo.

The length of the boiling process depends upon the concentration of the puree used. If it is of 1.06 specific gravity, the boiling need last a very few minutes only; merely long enough to mix the vinegar, spice extract, sugar and salt thoroughly. In such cases boiling is not continued long enough to permit adding spices to the catsup in a bag; a vinegar extract of the spices or essential oils or oleo resins must be used and very little boiling should be given after their addition, in order that loss of flavor and acetic acid may be avoided.

Many factories start with the raw non-concentrated pulp and concentrate it in an open kettle. If this method is used the spices may be placed in a bag in the pulp and the long boiling required for concentration will extract the necessary flavors. It is desirable to add a portion (about one-third) of the sugar at the start of the boiling process as this tends to intensify and fix the tomato color. The salt is not added until near the end of the boiling process, because it tends to bleach the color and to cause solution of copper from the coil or kettle. Spice extracts, oils or oleo resins and vinegar should be added near the end of the boiling period in order to avoid loss of volatile flavors such as essential oils and acetic acid. Approximately 3 gallons of raw pulp are required to make 1 gallon of puree of 1.06 specific gravity.

If salt is added direct to the boiling catsup it should be scattered over the surface so that it will not sink to the bottom of the kettle and fail to dissolve.

Determining the Finishing Point.—The cooking process is continued until the desired consistency is obtained. The end point is determined in most factories by specific gravity; although it is also customary to use a measured volume of puree and to condense this to a definite volume, which by experiment has been found to correspond to the final specific gravity desired. (See paragraphs on determining the specific gravity of puree.)

For the catsup formula given earlier, a final specific gravity of approximately 1.12 to 1.13 will give a catsup of satisfactory consistency. This density corresponds to about 25 per cent total solids, a large proportion of which consists of sugar and salt.

Finishing.—Catsup should be smooth in consistency and free from large pieces of spices, onion, garlic, etc. Therefore, when the desired specific gravity has been reached the hot catsup is passed through a finishing machine, which removes coarse material and overcomes any tendency of the product to become "grainy."

The acetic acid of the catsup attacks brass rather vigorously and for this reason the finisher screen should be made of more resistant metal, such as monel metal or bronze.

Bottling.—The hot finished catsup is in some factories run by gravity direct into bottles which have been previously thoroughly washed and are scalding hot at the time of filling. In other plants the catsup is transferred from the finisher to a jacketed kettle above the filling machine where it is heated nearly to the boiling point before being poured into bottles. A short direct pipe connects the heating vessel with the filling machine, so that very little cooling of the catsup occurs during transfer to the bottle. A steam-jacketed glass-lined pipe may also be used instead of a kettle to heat the catsup to 206°F. or higher before filling.

Pasteurizing.—If the catsup is heated to near the boiling point and is filled into hot sterilized bottles which are sealed immediately after filling, it is not necessary that the bottled catsup be sterilized or pasteurized. If, however, the temperature drops to 170 to 180°F. or less during the interval between finishing and bottling, it will be necessary, in most cases, to heat the catsup in the bottle in order to prevent spoilage.

A temperature of 180°F. for 45 minutes is ordinarily considered a severe enough pasteurization for catsup filled at above 170°F. Catsup is a very poor conductor of heat and the manufacturer should make heat penetration tests of his product in various sizes of bottles in order to adjust his pasteurizing time and temperature more intelligently.

If the catsup is not pasteurized, the filled and sealed bottles should be passed through a vat of hot water or beneath sprays of hot water to remove catsup adhering to the outside of the bottles; otherwise this catsup will dry tightly to the bottles and be difficult to remove.

Canning.—Some catsup is canned in No. 10 lacquered cans and if filled at above 180°F., no sterilization is necessary.

Sodium Benzoate.—At one time most catsup was preserved with $\frac{1}{10}$ of 1 per cent of sodium benzoate and often its use was associated with catsup of extremely poor quality.

Sodium benzoate is not used at present in any of the leading brands of catsup. The present-day manufacturer depends upon the acetic acid of

the vinegar and the preservative action of the spices to prevent spoiling after the bottle has been opened.

Yield.—For eastern conditions Campbell[12] states that 44 bushels of tomatoes (60 pounds per bushel), or 2,640 pounds, should yield about 264 gallons of puree of a specific gravity of 1.02, or 150 gallons of a specific gravity of 1.035 or 100 gallons of catsup of 25 per cent total solids. This corresponds to a yield of about 1 gallon of catsup from 2.64 gallons of pulp of 1.02 specific gravity.

Composition of Catsup.—Campbell[12] has reported analyses of eight typical catsups as given in Table 54.

TABLE 54.—ANALYSIS OF TYPICAL CATSUPS

(*After Campbell*)

	Packer							
	B.R	N.	H	S	S	L	L	G
Total solids, per cent	25.73	22.10	31.90	28.22	26.32	31.43	19.06	26.40
Acidity (acetic), per cent	1.20	1.26	1.70	1.70	1.49	1.54	0.83	1.39
Ash, per cent	3.66	3.31	3.76	.....	3.40	3.20	4.05	
Total sugar, per cent	14.78	12.16	20.44	19.08	16.54	22.00	9.66	18.90
Tomato solids, per cent	7.90	6.66	8.60	6.70	7.20	7.13	6.19	4.93

The present tentative standards for tomato catsup call for a minimum of 12 per cent tomato solids; an amount considerably higher than is shown above by Campbell's analyses.

Spoilage.—Catsup is subject to two types of spoilage or deterioration, namely blackening near the surface, and spoilage by microorganisms.

Blackening.—Investigation has shown that the blackening is caused by the formation of iron tannate and that the presence of air appears to be essential for the reaction.

Iron is dissolved in the ferrous condition from equipment coming in contact with the puree or catsup during manufacture or is dissolved by the acetic acid of the catsup from the metal of the bottle cap. In the presence of air, which may be present in the bottle because of slack filling, or which may have entered the bottle through a faulty cap, oxidation of the iron to the ferric state takes place. The ferric salts combine with tannin, extracted from the spices or from the stems and seeds of the tomatoes, to form a black finely divided precipitate of iron tannate. The heads of cloves have been found to be rich in tannin; hence the advice to use headless cloves.

Caps should carry heavy cork inner discs and the metal between the cork disc and cap should be lacquered. If the cases of catsup are stored with the bottles upside down, there is less danger of leaks occurring and consequently less danger of formation of the dark color.

Spoilage by Microorganisms.—Spoilage by microorganisms is most common after the bottle is opened, although if the product is not pasteurized and is filled into bottles at too low a temperature, molding or fermentation may occur in the sealed bottle.

Antiseptic Action of Spices and Condiments.—It has been shown by K. G. Bitting[13] that curry, ginger, mace, paprika, peppers and sage possess little or no antiseptic value in preventing the growth of mold or yeast. Allspice, cinnamon and cloves exhibit some antiseptic action on these organisms.

The active ingredients of these spices are the oils, extracted or added in the process of manufacture. Eugenol from the oils of allspice, and cloves and cinnamic aldehyde from oil of cinnamon are stated to be the active ingredients. According to Mrs. Bitting[13] these are present in very small concentrations in catsup, *e.g.*, approximately 1:138,000 and 1:259,000 and therefore exert very little antiseptic action. Hier[10] states that 1.25 per cent acetic acid will preserve catsup at least 2 weeks under normal conditions, long enough to permit the catsup to be consumed on the average table after the bottle has been opened. Acetic acid appears to be the most active preservative in catsup and in this respect is probably much more important than the spices.

The amount of sugar used in catsup is not sufficient to exert any appreciable antiseptic effect, its principal purpose being to counteract the acid taste of the acetic acid.

CHILI SAUCE

Chili sauce is made from whole peeled tomatoes and is not pulped or passed through a finisher at any stage of the process. It is used in large quantities as a flavoring in cooking and to some extent as a table relish.

Preparation of Tomatoes.—The tomatoes are peeled and cored as for canning, the same care in washing, sorting and trimming being taken as in preparing tomatoes for canning.

Flavoring.—Spices, onions, garlic, sugar, vinegar and salt are used in much the same manner as in catsup. Usually more cayenne, onions and garlic are used than for tomato catsup.

In most California factories the spices, onions and garlic are added to the vinegar and an extract made as described for catsup. This is added to the tomatoes near the end of the boiling process. In many factories the chopped onions and garlic are added direct to the tomatoes and remain in the final product.

One formula is as follows:

Whole peeled tomatoes	840	pounds
Chopped onions	35	pounds
Whole allspice	½	pound
Whole cloves (headless)	⅔	pound
Cinnamon (stick)	2½	ounces
Mustard	⅔	pound
Garlic (ground)	½	pound
Distilled vinegar (of 10 per cent acetic acid)	5	gallons
Salt	14	pounds
Sugar	60	pounds

The spices, except the cayenne and mustard, are heated in a covered vessel to the simmering point in the vinegar for about 2 hours. The peeled tomatoes are concentrated, preferably in a vacuum pan or glass-lined kettle, to about one-half their original volume with part (about one-third) of the sugar. The spiced vinegar, powdered cayenne, powdered mustard, salt and the remainder of the sugar are added near the end of the boiling process. The salt must be added slowly in order to make certain that it will dissolve or it may, if desired, be dissolved in the vinegar.

Spices can be extracted in a cloth bag in the boiling tomatoes as described for catsup, or may also be added in the form of oils or oleo resins.

Cooking.—The cooking is conducted in the same manner as for catsup and for the same purposes, namely, to concentrate the tomatoes and to blend the tomatoes and flavoring materials.

The end point is determined by appearance, although the tomatoes are usually weighed and concentrated to a definite volume as with catsup.

Bottling.—Wide mouth bottles are used because of the large pieces of tomatoes present in the sauce. An automatic rotary filler is used and the bottles are sealed with special caps in an automatic sealer. If filled boiling hot sterilization is not necessary; otherwise the bottles are pasteurized at 180 to 200°F. as described for catsup.

HOT SAUCE

An increasing amount of tomatoes is being used in hot sauce, a lightly spiced puree of hot flavor sold in small cans for flavoring in cooking. It can be prepared cheaply and frequently sells retail for 5 cents per 8-ounce can. Numerous formulas are in use, in which cayenne is the predominating flavoring. The following formula is typical:

To 700 gallons of raw pulp add the following ingredients finely ground:

	Pounds
Green chili peppers	100
Onions	75
Garlic	2½

Concentrate to about 425 gallons and add:

	Pounds
Ground cayenne pepper	2½
Salt	70

Stir thoroughly or boil a short time to dissolve salt and to mix the cayenne; can boiling hot and seal at once in 8-ounce cans.

In some cases the garlic is omitted and the proportions of other ingredients reduced in order to produce a sauce of milder flavor.

The tomatoes are sorted, washed, trimmed and pulped as in making puree, paste or catsup. The expense of hand peeling is therefore avoided.

THE MICROSCOPICAL EXAMINATION OF TOMATO PRODUCTS AND CHEMICAL CONTROL

If moldy, soured or fermented tomatoes are used in the manufacture of tomato products, microscopical examination will reveal the presence of excessive numbers of the organisms responsible for the decay. B. J. Howard[2] has made an exhaustive study of this subject and upon the results of his investigations the Bureau of Chemistry of the U. S. Department of Agriculture has established limits for the numbers of molds, yeasts and bacteria that may be permitted in tomato products.

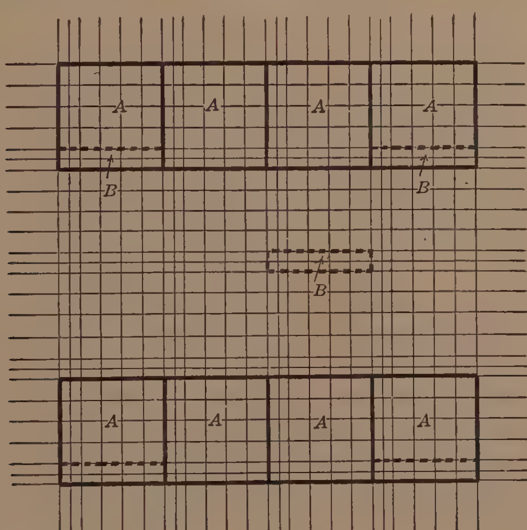

Fig. 70.—Rulings of Zeiss Haemetimeter used in the examination of tomato products.

THE HOWARD METHOD

This method was first published in Circular 68 of the Bureau of Chemistry, U. S. Department of Agriculture and was published a second time in 1917 in U. S. Department of Agriculture Bulletin 581. It has been adopted as a tentative method by the Association of Official Agricultural Chemists. The student is referred to the latter bulletin and Cruess and Christie's "Laboratory Manual" for details of the method.

Standards for Microorganisms in Tomato Products.—The Pure Food officials of the Bureau of Chemistry, U. S. Department of Agriculture, and of the various state boards of health consider tomato products unfit for food and subject to seizure and condemnation:

1. If mold filaments as determined by the Howard method are present in more than 66 per cent of the fields examined,
2. If yeasts and spores are present in excess of 125 per $\frac{1}{60}$ of a cubic millimeter as determined by the Howard method, or,
3. If bacteria in excess of 100,000,000 per cubic centimeter as determined by the Howard method are present.

Howard recommends a limit of 25 per cent for molds and it is perfectly feasible by careful sorting and by the use of sound material to produce, commercially, tomato products well below this suggested limit. The present standard of 66 per cent is very liberal. The same will apply to the present limits for yeasts and bacteria.

Interpretation of Results.—The presence of large numbers of mold filaments indicates the use of unfit moldy raw material or contamination of the pulp by uncleanly, moldy equipment. It usually indicates the former condition and calls for more careful picking in the fields and more rigid sorting and trimming.

The presence of an excessive number of yeasts, spores and bacteria usually indicates fermentation during a delay in the process of manufacture, although if the fruit is stored too long before pulping, fermentation and growth of these microorganisms may occur in cracked or crushed tomatoes before pulping.

Since the mold count is so much more important than the estimation of spores, yeasts and bacteria, it is the determination most frequently made by Pure Food officials and prospective purchasers of large quantities of tomato products.

Relation of Percentage of Rot to Mold Count.—It has been determined by Howard[2] that there is a fairly definite relation between the percentage of rot by weight and the mold count. Numerous determinations were made of the percentage of rot in 25- and 60-pound samples of the tomatoes from the sorting and trimming belts in a number of factories and of the per cent of fields of the finished pulp containing mold. The results of these determinations are shown graphically in Fig. 71.

None of the samples containing less than 1 per cent by weight of rot gave excessively high mold counts. While the results show that a low count may not always indicate the use of sound raw material, they clearly demonstrate that a high mold count always indicates the use of unfit material (provided the molds have not come from unclean equipment). Any weakness in this method of determining the quality of the product

favors the manufacturer and may occasionally permit products which should be condemned to pass inspection.

In the figure, percentages of rot above 20 per cent are plotted as if 100 per cent would give a count of 100 per cent of fields showing mold. As a matter of fact, a count of 100 per cent will often be obtained with pulp made from tomatoes containing less than 20 per cent of rot by weight.

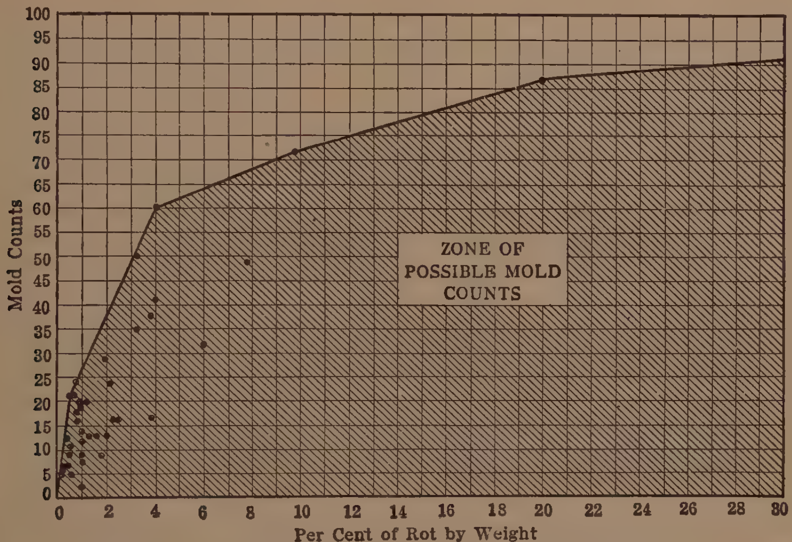

FIG. 71.—Relation between percentage of rot in fresh tomatoes and mold count in pulp. (*After Howard*).

From the chart it is possible to estimate the minimum per cent by weight of rot in the raw material. Thus a mold count of 40 enters the "Zone of Probable Mold Counts" at a point representing 2.2 per cent of rot by weight. A count of 40, therefore, may represent from 2.2 to 100 per cent by weight of rot in the raw material, but not less than 2.2 per cent.

Relation of Per Cent of Rot to Bacteria, Yeast and Spore Counts.—Counts of less than 15,000,000 bacteria per cubic centimeter indicate little as regards per cent of rot in the original material, but above this point, according to Howard,[2] each per cent increase in weight of rot gives an increase of about 20,000,000 bacteria per cubic centimeter. This relation holds to about 20 per cent by weight of rot. A low bacterial count does not always indicate the use of unfit material.

The same general relations exist for yeasts and spores as for bacteria.

Effect of Peeling on Counts of Microorganisms.—Chili sauce and canned tomatoes are prepared from peeled and well-trimmed stock in most cases and as a consequence extremely low counts of molds, yeasts and bacteria are the rule for such products.

Effect of Method of Storage of Pulp.—In former years it was customary to store tomato pulp (to be used for catsup, etc.) in wooden barrels with distilled vinegar or sodium benzoate as a preservative. Almost invariably such pulp has shown on microscopical examination after several months' storage very high counts of bacteria and often high mold counts.

Because of the frequent condemnation by the food officials of barrel stock, this method of storage is rapidly going out of existence and is being replaced by sterilization in 5-gallon or No. 10 cans.

Effect of Concentration.—In highly concentrated tomato products, such as tomato paste, the increase in numbers of mold filaments is not strictly proportional to the degree of concentration. Thus if tomato pulp is concentrated 10 : 1 the molds will not increase in a similar ratio, but will show a considerably smaller increase, probably because of breaking up of the filaments and shriveling of the mold filaments by osmosis to such an extent that they are no longer recognizable under the microscope as molds.

This condition exists to a more limited extent with other concentrated tomato products, such as catsup, highly concentrated puree, etc., although it is most pronounced in tomato paste.

For this reason food officials have experienced difficulty in establishing standards for tomato paste.

Accuracy of the Howard Method.—Some food chemists and manufacturers of tomato products are inclined to doubt the value of the Howard method as a means of detecting spoilage or the use of unfit raw material. It has been proved many times, however, that the method in the hands of experienced analysts gives strictly comparable results and that it is possible to obtain results upon the same sample that agree closely. It has also been shown that any error in the method is more liable to favor the manufacturer than the food official. Its principal weakness lies in the fact that it does not always give a high count with products known to have been prepared from tomatoes containing an excessive amount of rot.

LABORATORY CONTROL

Value of Microorganism Counts.—The foregoing considerations have shown the importance to the manufacturer of knowing at all times that his product conforms to the standards established by law for tomato products. For this reason, if for no other, a laboratory should be maintained for the inspection of every batch of tomato pulp or other tomato product produced.

Manufacturers of large quantities of tomato pulp and catsup have also found that guaranteed reports upon the microorganism counts of their products have very definite advertising value.

Analyses of the pulp and finished products at the time of manufacture enable the plant superintendent to detect careless sorting and trimming at once on the arrival at the plant of tomatoes that carry excessive numbers of microorganisms.

Specific Gravity.—In addition to examining tomato products microscopically the chemist is of very great value to the tomato products factory in controlling the specific gravity of the pulp, etc. The average cannery workman cannot be trained to make reliable determinations of specific gravity. Boiling the pulp to a definite volume, or use of some other more or less "hit or miss" method of determining the finishing point for pulp without laboratory control, leads to heavy losses in one of two ways. Either the product is liable to be frequently below the gravity demanded by the purchaser and a damage suit, rejection or price penalty ensues, or the product is too highly concentrated and a low yield is thereby obtained, with consequent loss to the manufacturer and gain to the purchaser.

The magnitude of such loss may be indicated by the following consideration. If the manufacturer desires to produce puree of a specific gravity of 1.035 to fill a contract and, having no chemist, concentrates the puree to an average of 1.04 he will find that his yield will be reduced in the ratio of 100 to 114.7; that is, 114.7 gallons of pulp of 1.035 is equal to only 100 gallons of 1.04 specific gravity. On an output of 10,000 gallons of pulp per day this corresponds to a daily loss of 1,470 gallons. In addition to the direct value of the chemist there is the indirect increase in value of the product due to improved quality.

The time of the chemist can be utilized to advantage during the dull season of the year in investigations of the utilization of by-products and in devising new products that will prolong the operating season of the plant.

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CHAPTER XX

THE SUN DRYING OF FRUITS AND OF VEGETABLES

The preservation of foods by drying is one of the oldest and most important of the food industries and considerably more fruit is preserved by drying than by any other means.

Until relatively recently, Asia Minor, Greece, Spain and other Mediterranean countries produced most of the world's supply of sun-dried fruits; but California has now become the most important producer of raisins, dried peaches, prunes and apricots. Although the date industry in that state is becoming important, the total production is relatively small compared to that of Egypt and Asia Minor.

New York and the Pacific Coast States produce the bulk of the dried apples in the United States, but this fruit is dried by artificial heat and not in the sun.

Extent of Industry in California.—Except in California almost no fruit is sun dried in the United States. The extent of the industry is indicated by the data in Table 55.

TABLE 55.—PRODUCTION OF SUN-DRIED FRUITS IN CALIFORNIA

Fruit	1903–1907, average tons	1917, tons	1919, tons	1921, tons
Apricots	8,200	15,000	14,500	6,500
Figs	3,000	2,000	11,000	6,500
Peaches	14,500	5,000	35,000	22,000
Prunes	67,500	115,000	135,000	112,500
Raisins	54,000	163,000	187,575	122,500
Pears	No data	No data	No data	2,500
Dates	No data	No data	No data	1,000
Total	147,200	300,000	383,075	273,500

Advantages of Dried Foods.—Dried foods are in more concentrated form than foods preserved in other ways. They are less costly to produce than canned or preserved food, because of lower labor costs and the fact that no sugar is required.

Dried fruit requires less storage space and a smaller number of cartons or boxes than an equivalent amount of fruit in canned or preserved form.

A ton of apricots after canning weighs approximately 2,800 pounds, if the weight of cans and boxes is included. A ton of fresh apricots yields about 400 pounds of dry fruit, which when packed will weigh not more than 450 pounds, or less than one-sixth as much as the equivalent amount of canned fruit.

With vegetables the difference in weight of the dried and canned articles is even more striking.

It can readily be seen that the cost of transportation will be very much less for dried than for canned or fresh fruits and vegetables.

For these various reasons dried fruits are usually considerably less costly to the consumer than the equivalent quantities of canned or preserved fruits.

EQUIPMENT FOR SUN DRYING

The equipment used for the drying of fruit varies considerably with the variety of fruit to be dried and with local conditions, but there are certain pieces of equipment that are common to several varieties of fruit.

The Dry Yard.—Fruits are transported from the orchard to a centrally located yard to be dried, with the exception of the grape, which is usually dried in the vineyard between the rows of vines.

The term "dry yard" is usually taken to include both the area used for the trays of drying fruit and the buildings and equipment that are used in preparing and storing the fruit.

The area required for the dry yard varies with the variety of fruit to be dried, the yield per acre and with local weather conditions. Less area is required in a region where the temperature is high and the humidity is low than is required in a region of cool days and foggy nights. Under California conditions the ratio of the dry yard area to bearing orchard or vineyard area is: for prunes, from 1:10 to 1:40, with an average of about 1:20; for apricots, from 1:10 to 1:25, with an average of about 1:22 and for pears, about the same ratio as apricots except in localities where most of the drying is done under sheds, where the area required is less than for apricots. Peaches require about the same drying area as apricots and pears and figs require less space than apricots. Dates are usually allowed to dry on the trees.

The dry yard should be protected from dusty roads and the driveways in the yard should be sprinkled frequently or oiled to prevent the accumulation of dust on the drying fruit. The yard should not be near stables or other breeding places for flies. Bees become a serious pest during the late summer and early fall months if the hives are near the

yard. In very windy sections the yard should be protected by a wind break.

The yard should be so designed with reference to the dipping and cutting sheds that the fruit can be handled efficiently and it should be near the orchard. Figure 72 illustrates a suitable dry yard layout as designed by A. W. Christie and L. C. Barnard of the University of California.

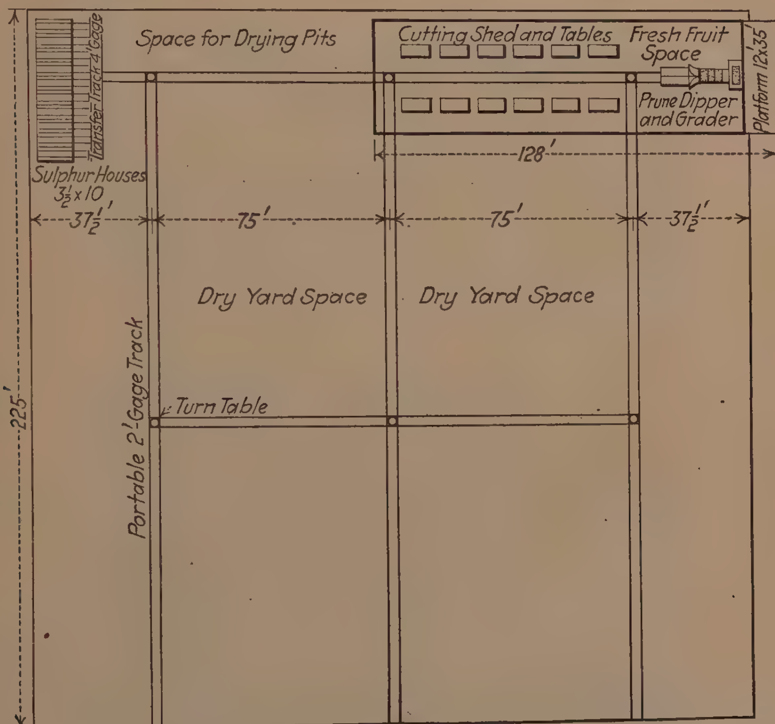

FIG. 72.—Ground plan of a fruit drying yard of approximately 2½ acres. (*After Christie and Barnard*).

Cutting and Dipping Shed.—The fruit cutters and other workmen engaged in the preparation and traying of the fruit should be protected from the sun. An open shed, equipped in large yards with car tracks, cutting tables and dipping equipment, is usually built for this purpose.

The shed should be so designed and equipped that the fruit may be carried through it during cutting, dipping, etc., in the most efficient and direct manner possible and with the minimum of confusion.

Sulphuring Equipment.—Pears, peaches and apricots are exposed to the fumes of burning sulphur before the fruit is placed in the dry yard. The usual sulphur house for peaches and apricots consists of a wooden, brick or concrete chamber a few inches longer and wider than the trays and high enough to accommodate a dry yard car loaded with 20 to 25

trays. The fruit is sulphured by burning sulphur in a small pit in the floor of the sulphur house for the required length of time, for most fruits 3 to 6 hours.

Figure 74 illustrates the appearance of typical sulphur houses.

A cheap and convenient form of sulphuring device is the "balloon hood," which consists of a light wooden frame covered with heavy roofing or building paper or canvas made airtight with tar paint. This

FIG. 73.—Upper: Typical cutting shed for pears and apricots. Center: Large concrete cutting shed for apricots. Lower: Hauling apricots to the drying yard.

light chamber can be placed over a stack of trays in the dry yard, making the use of cars unnecessary. It is not very durable and is probably less convenient than the standard sulphur house.

Brick or concrete sulphur houses are permanent and more nearly fume tight than wooden structures. It is desirable to equip the sulphur box with an adjustable opening in the roof to provide proper ventilation for continuous burning of the sulphur and distribution of the fumes.

Placing the sulphur burning pit at the rear of the sulphur box is desirable because the fumes from the pit then do not annoy the workmen

so much during placing of the trays in the box and during removal of the car of trays after sulphuring. A small door is cut in the rear wall of the sulphur box to permit lighting of the sulphur in the pit.

Transfer Systems.—The trays are usually transported in the yard by means of small cars on light steel rails. The cars are low and fitted with wooden frames of the size of the trays and are moved by hand (see Fig. 74).

Fig. 74.—Houses for sulphuring cut fruit. Note method of staggering trays in upper picture to facilitate contact of sulphur fumes with fruits.

Turntables or transfer cars and tracks are used for transferring the cars at right angles to the main track.

The track system should be carefully planned in order that all portions of the dry yard may be conveniently reached and so that loaded cars may be transferred to the yard and empty cars from the yard to the preparation shed without confusion. The track system shown in Fig. 72 is satisfactory.

In some yards the trays are hauled on low wheeled wagons by motor power or by horses. This method of transfer is more flexible than the track and car system, but probably more costly in operation.

Trays.—The tray universally used in California is made of pine or redwood shakes on a light wooden frame.

The sizes in most common use are as follows: 2 by 3 feet with ends or sides open, used for grapes and figs; 3 by 3 feet with ends open, used for prunes and grapes; 3 by 6 feet, ends and sides usually closed, used for prunes, pears, grapes, apricots and peaches; 3 by 8 feet, ends and sides closed, used principally for prunes, but also for apricots, peaches and pears.

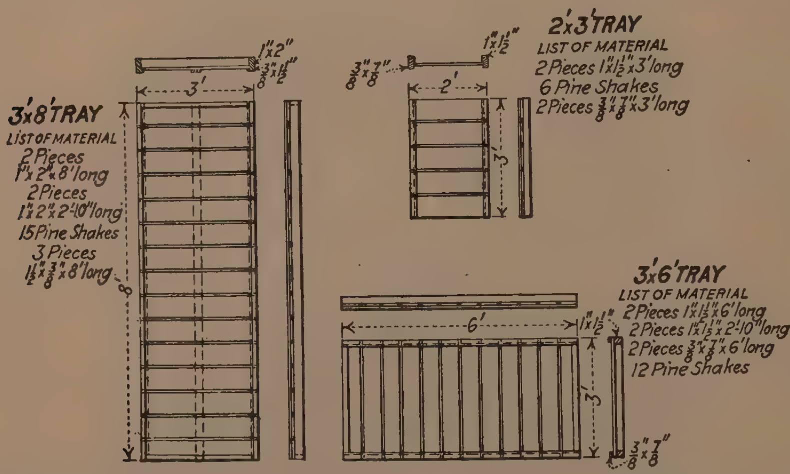

FIG. 75.—Sketches of various sun-drying trays with lists of materials. (*Sketch by Barnard*).

The lists of materials for the 3- by 8-foot and 2- by 3-foot trays are as follows:

3- BY 8-FOOT TRAY	2- BY 3-FOOT TRAY
2 pieces, 1″ × 2″ × 8′	2 pieces, 1″ × 1½″ × 3′
2 pieces, 1″ × 2″ × 2′ 10″	6 pine shakes, 6″ × 3′
15 pine shakes, 6″ × 3′	2 pieces, ⅜″ × ⅞″ × 3′
3 pieces, 1½″ × ⅜″ × 8′	

The appearance of the various trays is shown in Figs. 74, 88 and 77.

Cutting Tables.—Peaches, pears and apricots are cut in half and pitted or cored before being placed on the drying trays, which rest on a table in front of the cutters. In its simplest form the cutting table consists of two sawhorses or several lug boxes upon which the tray rests.

A well-built table is more rigid and convenient than the sawhorse or lug box supports. A convenient cutting table devised by L. C. Barnard, of the University of California, consists of a frame 3 feet in width and 8 feet long. This will accommodate four 2- by 3-foot trays, three 3- by 3-foot trays or one 3- by 6-foot or 3- by 8-foot tray. The top of the frame is at a convenient height for the cutters, about 33 inches from the ground.

At the sides of the table are supports for lug boxes, from which the fruit can be readily taken to be cut and spread on the trays.

The cutting tables are movable and are placed in the cutting shed in such position that the fruit and trays may be carried to and from the tables conveniently.

Boxes.—The fresh fruit is usually transported to the dry yard in lug boxes holding 40 to 60 pounds of fruit.

The dried fruit is either stored in bins or is placed in sweat boxes, which are pine boxes about 10 inches deep and 3 by 4 feet in size. Sweat boxes are more generally used for raisins than for other dried fruits.

Storage Space for Dried Fruit.—Dried fruit must be protected from insects during storage. A room, therefore, should be provided which is insectproof and which may be fumigated with carbon bisulphide or other gas or vapor.

The store room is equipped with bins, usually rectangular and 4 to 8 feet deep, in which different lots of fruit may be stored separately. The front wall of each bin is made of removable boards to facilitate filling and unloading. In some cases the dried fruit is placed in heaps on the store room floor and bins are dispensed with.

"Sweating" of the fruit, that is, equalization of the moisture in the fruit and softening of the skins by moisture from the interior of the fruit, is considered an essential step in the process of drying and curing. The bins facilitate the sweating process.

Other equipment will be discussed under drying of the various fruits.

Lye Dipping.—Prunes, and in some sections grapes, are dipped in a dilute solution of sodium hydroxide, sodium carbonate or other alkaline solution for the purpose of removing the wax coating and checking or slightly cracking the skins of the fruit in order to increase the rate of drying.

The simplest form of lye dipping apparatus consists of a heavy cast-iron kettle filled with dilute lye solution and mounted over a wood-burning furnace. The fruit is dipped in the kettle of boiling lye solution by means of a small woven wire basket holding 25 to 50 pounds of fruit.

A very common form of dipping outfit used by small dry yards consists of a brick furnace about 6 feet high in which is set a rectangular sheet metal tank containing the lye solution. At one side of the dipping outfit is an unloading platform on which the lug boxes of fresh fruit are placed and on which the workman who operates the dipping outfit stands (see Fig. 76). A rectangular basket with rounded bottom holds the fruit during dipping and is operated by a hand lever. A second tank and a second basket may be placed beyond the first basket for rinsing the lye-dipped fruit. Prunes are usually not rinsed, whereas grapes are generally thoroughly rinsed to remove all adhering lye solution. The lye tank is usually heated by an oil burner.

Continuous dipping machines similar to that shown in Fig. 76 are used in some large dry yards. The spray type of lye peach-peeling machine has proved very satisfactory for dipping prunes and grapes for drying.

Sodium hydroxide is generally used in preference to other alkaline substances in the dipping solution, although sodium carbonate and mixtures of sodium carbonate and sodium hydroxide are used to a limited

FIG. 76.—Lye-dipping equipment for prunes and grapes. Upper: Dipping prunes. Lower left: Continuous grape dipper. Right: Hand power prune dipper.

extent. Sodium bicarbonate is sometimes used for the dipping of Sultana grapes, but its action is not severe enough for prunes or tough-skinned grapes.

The concentration of the lye dipping solution varies according to the variety of fruit, its maturity and the district in which the fruit is grown. The maturity of the fruit also affects the strength of the solution necessary to check the skins satisfactorily. Green fruit requires a more concentrated solution than ripe fruit of the same variety. Prunes grown in the hot interior valley of California require stronger solutions for dipping than those grown in the coast countries.

PRUNES

In the past almost the entire prune crop in California has been dried in the sun. In 1918 the industry suffered a loss of approximately $5,000,000 because of early fall rains which caused the spoiling of the fruit on the trays. Since that date interest in the use of dehydraters has increased and at present a considerable and increasing proportion of the crop is being dried by artificially produced heat.

Varieties.—The French prune (*Petite Prune d'Agen*) is the principal variety grown in California. The trees of this variety produce regularly and heavily but the fruit is smaller than that of most other varieties grown commercially in California.

The Sugar prune, the second in importance in California, is larger than the French prune and ripens several weeks earlier than the latter. The skin of the Sugar prune is more tender than that of the French prune and therefore more easily checked in lye dipping. It molds and ferments more readily than the French variety and for this reason requires more care during drying and it does not bear as heavily as the French prune.

The Imperial prune is a very large variety, but the tree does not bear as regularly nor as heavily as the French variety. It is a very difficult fruit to dry successfully in the sun, because of fermentation and darkening of the flesh near the pit, but when properly dried commands a premium because of its large size. It can be dehydrated easily, a fact which should eliminate the principal objection to it.

The Robe de Sargent is a variety grown in limited quantities only. It is less desirable than the French prune, since it is no larger than the latter and usually contains less sugar.

Several selected and new strains of the French prune are being advocated at the present time by nurserymen. The most promising of these new strains is probably the Coates "1418" prune.

The Silver Plum is sulphured and dried in the sun to a limited extent.

The Italian prune is not grown commercially in California for sun drying, although it is the principal variety grown in the Northwest for evaporating purposes.

Harvesting.—In California, prunes are allowed to ripen on the tree and to fall to the ground of their own accord. They are then picked from the ground by hand into lug boxes. At the end of the season fruit which has not ripened sufficiently to fall of its own accord is shaken or knocked from the trees, but this fruit is not as sweet or of as good a color as that which ripens and falls naturally.

The fruit should not be allowed to lie on the ground too long, because it is liable to mold or become partially dried and difficult to check by lye dipping.

The orchard soil should be rolled at the beginning of the season in order that the fruit will be injured as little as possible and that picking may be facilitated.

Usually four to five pickings are made during the season.

Dipping and Size Grading.—At the dry yard the prunes are dumped from the lug boxes into the dipping machine. For French prunes the lye solution varies from 0.25 to 1.5 per cent according to the maturity of the fruit and the locality. In the Sacramento Valley the stronger solution is used and in the Santa Clara Valley and other coastal regions

solutions of approximately 0.5 per cent are generally employed. The above percentages correspond to about 4 to 12 pounds of lye per 100 gallons of water.

Length of Dipping.—The prunes remain in the lye solution from 5 to 30 seconds, the average time being approximately 15 seconds. The rotary automatic dipper is used in the large yards and the hand power basket dipper in the small yards.

Fig. 77.—Upper: Soaking and washing prune drying trays. Lower: Transfer car and tracks to sulphur houses. Right: Prune drying trays.

Sugar prunes require a weaker lye solution than French prunes and a shorter period of dipping. The Imperial prune is more tender than either the French or Sugar varieties and is dipped in a very dilute solution (0.25 per cent) or in boiling water only. Some growers place Imperial prunes undipped on the trays in the sun for several days before dipping, in order to shrivel and toughen the skins slightly.

Needle-board.—At one time most prunes were passed over a needle-board after dipping, in order to puncture the skins. This practice has now been discarded in most yards.

Size Grading.—Prunes should be graded for size after dipping, in order to promote uniformity of drying, because much of the small fruit is partially dried before it arrives at the yard and becomes overdried if mixed with the larger fruit. In most yards two or three grades only are made. In some yards the slabs or culls are separated from the remainder of the fruit by hand and dried on separate trays.

Appearance of Dipped Fruit.—A properly dipped prune should exhibit very small cracks over its entire surface; the skins should not be partially peeled from the fruit nor should any great proportion of the

fruit pass through the dipper without checking of the skins. If the solution is too weak the prunes must be submerged in the lye for such a long period that many of them become partially cooked and some burst or are partially peeled. If the lye solution is too strong the fruit is apt to be partially peeled or the cracks in the skin too large. It is desirable that the solution be maintained actively at the boiling point for the best results.

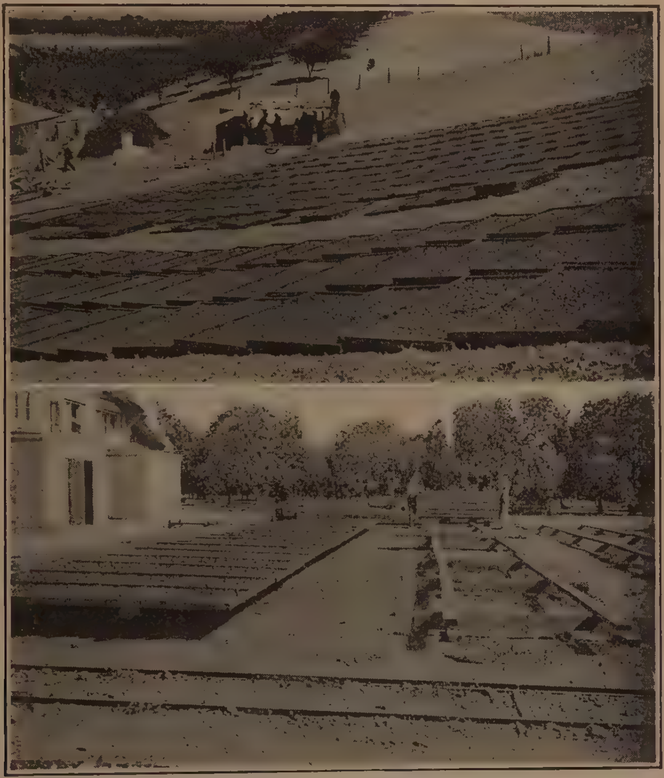

FIG. 78.—Apricot drying yards. Note tray racks in lower picture.

Renewing the Solution.—In most yards the lye solution is replenished from time to time during the day by the addition of fresh lye in granular form and by adding water to replace that lost by evaporation, neutralization and by adhering to the fruit. It becomes necessary to remove the lye solution occasionally and replace it with freshly prepared solution because of the accumulation of sugar, dust and salts of sodium.

Rinsing.—Prunes are generally not rinsed after dipping, although rinsing improves their appearance.

Traying.—The dipped prunes fall from the grader or dipper to trays placed in the proper position to receive the fruit (see Fig. 76).

The tray most commonly used is 3 by 8 feet in size and when the prunes are placed on the tray one layer deep holds approximately 75 to 90 pounds of fruit. The fruit is spread by hand.

The loaded trays are stacked on a waiting dry yard truck, usually about 20 trays per truck and taken to the dry yard.

Spreading and Drying in the Sun.—The trays are spread in rows on the ground as shown in Fig. 78 with pathways between the rows to permit handling of the fruit and tray during drying.

Sugar and Imperial varieties usually require stirring to prevent molding, after the fruit has been on the trays for 3 or 4 days.

Stacking.—After the prunes have become two-thirds to three-fourths dry, the trays are stacked one above the other in such manner that the air may pass freely between the trays and drying is allowed to continue in the stack. If dried completely in the sun, much of the fruit is apt to be overdried.

In good drying weather the trays may be stacked within 4 or 5 days after dipping.

Removal from the Trays.—The fruit is dried to a moisture content of approximately 12 to 18 per cent. The grower determines the end point by the feel of the fruit. The pit in a properly dried prune should not slip between the fingers when the prune is pressed and the texture should be leathery and the flesh firm. The prunes should not be so dry that they rattle on the trays. Overdried fruit results in low yields, while underdried fruit will spoil in the storage bins.

The fruit is carefully sorted before it is removed from the trays in order to remove "bloaters" (insufficiently dried immature fruit), slabs (broken or over-ripe fruit) and split or otherwise damaged fruit.

The remaining fruit is then scraped from the trays into lug boxes and transported to the storage bins.

Sweating.—The dried fruit is placed in bins built for the purpose or is heaped in piles on a clean floor to undergo sweating, or equalization of the moisture. The overdried fruit absorbs moisture from the fruit of higher moisture content and the surface of the fruit becomes moist through the diffusion of moisture from the interior of the fruit to the surface.

Sweating usually lasts 2 weeks or longer. In some yards sweating is dispensed with and the fruit is taken directly to the packing house from the dry yard in lug boxes or sacks.

Delivering to the Packing House.—The sweated fruit is usually placed in bags for transportation to the packing house, where the fruit is weighed and samples are taken for the door test, which consists in counting the number of prunes per pound. The grower is paid upon this basis. Further information concerning size grades will be found in Chapter XXII.

Yields.—In California the normal drying ratio for French prunes is about 2.4:1, that is 2.4 pounds of fresh fruit is required to produce 1

pound of dry. Yields as high as 1.8:1 and as low as 3:1 are obtained, depending upon the maturity of the fruit.

The average yield of dry fruit per acre of bearing orchard is about 2 tons.

Labor and Costs for Prunes.—According to data collected by A. W. Christie and L. C. Barnard of the College of Agriculture of the University of California, the average labor cost for drying prunes in 1921 was approximately $3.43 per green ton.

Silver Plums.—Silver plums, or Silver "prunes," a large white variety of plum, is dried in California to a limited extent. The plums are lye dipped, as described above for other varieties of prunes, are placed in the fumes of burning sulphur for at least 4 hours and are then placed in the sun to dry. The drying operations are similar to those for other prunes. The dried product is of amber color and of acid flavor.

SUN DRYING MUSCAT GRAPES

The drying of raisins is the most important fruit drying industry. California, Greece, Asia Minor and Spain produce most of raisins of the world. Greece is noted for its dried currants, a small raisin made from currant grapes (not currants in the ordinary sense of the word). Spain produces principally Muscat and Malaga raisins and several varieties of seedless raisins are dried in Asia Minor. Smyrna is one of the most important ports for the shipment of raisins from Asia Minor.

Cooperative Association in California.—The raisin growers of California in 1912 organized a cooperative marketing organization to market the 70,000 tons of raisins produced in the state at that time, which were then selling at a loss. An advertising campaign resulted in selling all of the surplus and in placing the raisin growing industry on a paying basis. Since that year the planting of vines has increased rapidly until at the present time California is producing approximately 250,000 tons of raisins annually.

The following table gives the plantings and production from 1916 to 1922 inclusive.

TABLE 56.—PLANTING OF RAISIN GRAPES IN CALIFORNIA AND PRODUCTION OF RAISINS SINCE 1916

(After Sun-Maid Raisin Growers' Statistical Department, 1922)

Year	1916	1917	1918	1919	1920	1921	1922*
Acreage	162,381	164,547	201,991	256,452	292,938	360,076	400,375
Tons	132,000	163,000	167,000	182,500	173,500	150,900	234,800

* Tonnage for 1922 is estimated.

The Association has a membership of 14,000 growers. The growers harvest and dry the grapes and may also sort out cluster raisins before delivery. The raisins are then delivered by the growers to the Association's packing plants or receiving stations. Payment to the extent of not more than 50 per cent of the value of the raisins is made the growers by the Association within 6 days after delivery. Final payment is made after the fruit has been sold, or at intervals during the year after receipt of the raisins at the packing houses.

The association makes with the growers a contract for a period of several years which has been proved in court to be binding on both parties. This contract gives stability to the organization and is, undoubtedly one of its more important features.

Relation of Maturity to Yield and Quality.—It is customary to begin harvesting the Muscat grape for drying in California at about 21° Balling, *i.e.*, when the juice expressed from the grapes tests 21° by the Balling hydrometer. Bioletti[2] has made a thorough study of the effect of maturity on yield and has obtained rather startling results. His experiments have been confirmed by F. K. Howard and others. The following table illustrates the results obtained:

TABLE 57.—EFFECT OF MATURITY ON THE YIELD AND RETURNS FROM MUSCAT GRAPES

One acre, 1913 and 1914
(*After Bioletti*[2])

Balling of juice at time of picking	Pounds of raisins per acre	Gross returns per acre	Cost per acre	Net profit per acre	Increase in profit per acre per cent
18	1,786	$ 89.30	$47.90	$41.40	0.00
19	1,893	94.65	48.70	45.95	8.57
20	2,000	100.00	49.50	50.50	21.98
21	2,107	105.35	50.19	55.16	33.24
22	2,214	110.70	50.88	59.82	44.49
23	2,321	116.05	51.57	64.48	55.75
24	2,428	121.40	52.26	69.14	67.00
25	2,535	126.75	52.95	73.80	78.26
26	2,642	132.10	53.64	78.46	89.52
27	2,749	137.45	54.33	83.12	100.77
28	2,856	142.80	55.02	87.78	112.03

From these results it can readily be seen that it is extremely important that grapes for drying should be fully matured. The principal reason that grapes are picked before they have reached their maximum sugar content is that, because of labor shortage, it is often difficult to pick all the grapes before there is loss from early fall rains. Many growers are

now, however, insuring against rain damage by erecting dehydraters to be used during seasons of early rains. Where this provision is made it is possible to delay harvesting until the grapes have attained at least 24 to 25° Balling. Grapes harvested immature yield not only a smaller total amount of dried product, but also raisins of smaller size and of poorer texture and color.

Preparing the Vineyard for Drying.—The rows of vines run in an easterly and westerly direction, in order that the trays will not be shaded during the morning and afternoon. A furrow is plowed on the north side of the row, in order that the trays will be tilted toward the south and thus receive the full rays of the sun. The forming of this furrow is known as "V-ing."

Harvesting.—After the furrow has been made and the grapes have attained the desired maturity the trays, 2 by 3 feet in size, are taken to the vineyard and distributed to the different rows. The grapes are picked directly onto the trays which are placed between the vines and are tilted toward the south. In most vineyards approximately 22 pounds of fruit are placed on each tray.

The grapes must be spread evenly and to a depth of one bunch only. Picking is done by piece work, the usual price per tray in 1921 being 3½ cents or approximately $3.15 per fresh ton.

A short knife with curved blade is used for cutting the bunches of grapes from the vines.

Turning.—After the grapes have partially dried, the trays are turned by placing an empty tray over a filled tray, then quickly and deftly reversing the trays and removing the empty tray. The bottoms of the bunches are thus exposed to the sun and drying is hastened and made more uniform. Under usual drying conditions about 10 days' exposure to the sun is required before the grapes are ready to turn.

Turning should be carefully done, so that the bunches will be broken as little as possible and a maximum yield of cluster raisins obtained.

Stacking.—As in the drying of other fruits in the sun, the last stages of the drying process are conducted in the shade, *i.e.*, by stacking the trays in order to protect the fruit against the direct rays of the sun. Stacking is done when it is no longer possible to express juice from the berries by pressure between the fingers, which will be normally 5 to 6 days after turning. The grapes are left in the stack until sufficiently cured to be accepted by the packing house, usually after about 1 week in the stack. The total drying period under normal drying conditions is therefore about 3 weeks. In cool weather it may require 6 weeks to dry the grapes sufficiently, and in very hot weather less than 3 weeks.

Placing in Sweat Box.—There is a good demand for raisins in the bunch for fancy packages for the holiday trade. These raisins are used for dessert purposes and are known as "layers" or "clusters," and the

grower is paid a premium for such fruit. When the grapes are dry (about 15 to 17 per cent moisture) the trays are sorted to remove the large and perfect clusters, which are placed in sweat boxes, care being taken not to break the bunches.

Raisins not suitable for clusters are dumped into sweat boxes. The raisins are very easily removed from the trays, as there is no tendency for the fruit to stick to the smooth wooden shakes used for tray bottoms and because the grapes are not dipped and therefore do not exude juice or syrup, as do prunes and cut fruits.

Sweat Boxes.—Sweat boxes are almost universally used as containers for the raisins. These boxes are approximately 3 by 4 feet and about 10 inches deep, about 150 pounds of raisins being placed in each sweat box. By pressing the raisins, the box can be made to hold a larger quantity, but this practice is objectionable because it may result in breaking of the berries and stems, making it difficult to stem the raisins in the packing house.

The raisins should be left in the sweat boxes for at least 3 weeks before delivery to the packing house in order that they may equalize in moisture content and remain fairly constant in moisture content during storage at the packing house.

Cost of Producing Muscat Grapes.—Table 58 gives typical cost data for the production of Muscat raisins in California in 1920.

TABLE 58.—COST OF MUSCAT RAISIN PRODUCTION FOR YEAR 1920

On basis of 1 acre and yield of ¾ ton per acre

(*After D. H. Gray*[3])

Labor	$ 67.43
Taxes and insurance	11.82
Depreciation, total	27.88
Interest	48.00
Management	32.05
Miscellaneous	46.40
Total	$233.58

The return for a ¾-ton crop at 11 cents per pound is $165, yielding a net loss of $68.58 per acre. Similarly a 1-ton per acre crop yields a loss of $22.10 and a 2-ton crop a profit of $163.65, according to Gray.

Drying of Seedless Grapes in California.—The principal seedless variety grown in California is the Sultanina or Thompson Seedless, a variety which comprises more than 90 per cent of the total crop of seedless grapes in that state. The Sultana is second in importance. Two varieties of currant grapes, the Black Corinth and the White Corinth, are grown in very small quantities.

Undipped Sultanina.—The Fresno district is the principal producer of Thompson Seedless raisins, where most of the seedless grapes are dried

in the same manner as described above for the Muscat grape. The grapes are not dipped in lye or otherwise treated before drying, but are picked direct from the vines on the trays. In some vineyards paper trays made of heavy wrapping paper are used and these are of the same dimensions as the wooden trays. They are much less satisfactory than the wooden trays and their only merit is their low original cost.

Thompson seedless grapes should not be picked until the juice has attained at least 24° Balling.

Because of the larger size of the bunches a larger weight of Sultanina grapes than of Muscats can be placed on each tray. The Sultanina yields more heavily than the Muscat and plantings of this variety have been much heavier than of Muscat.

Soda-dipped Sultanina Raisins.—In the Sacramento Valley of California grapes ripen 2 to 3 weeks later than in the Fresno district in the San Joaquin Valley. Most of the grapes are, therefore, lye dipped in order to hasten drying, so that the grapes may be dried before the rainy season.

Lye Solution.—At the dry yard the grapes are dipped in a boiling dilute lye solution in a manner similar to that described elsewhere for prunes. The concentration of the lye varies from about 0.1 to about 0.75 per cent sodium hydroxide, the most desirable concentration being about 0.5 per cent sodium carbonate, or a mixture of sodium carbonate and sodium hydroxide, is used in some yards. The length of immersion in the lye solution is from 3 to 6 seconds, and the grapes are rinsed in water immediately after lye dipping.

Dipping Outfits.—The "merry-go-round" dipper, the most commonly used type of dipping outfit, consists of two or more hinged wire baskets suspended from the ends of levers which, in turn, are hinged to a central, pivoted upright. The baskets are filled with grapes, immersed in the boiling lye solution a few seconds, rinsed in water and the grapes spread on 6- by 3-foot trays.

The skins of properly dipped grapes should exhibit an evenly checked surface.

Spreading in Yard.—The trays are spread in the dry yard directly from the dipping shed and are turned after the grapes are from one-half to two-thirds dry, in normal drying weather 3 to 5 days after dipping. After 2 or 3 days' further exposure the trays are stacked to complete the drying process.

After drying, the raisins are transferred to lug boxes or sweat boxes and taken to the stemming and packing house, which is frequently part of the dry yard equipment. The raisins are light brown in color and superior to the bleached raisins in flavor.

Oil-dipped Sultanina and Sultana Raisins.—So called "oil-dipped" raisins are prepared by dipping the fresh grapes in a cold solution of

sodium bicarbonate on the surface of which is a thin layer or film of olive oil. The usual concentration of bicarbonate is 28 pounds per 100 gallons.

This solution does not check or crack the skins of the grapes and apparently merely removes the wax and bloom. The grapes are coated with a very thin film of oil as they emerge from the dipping solution and this causes the dried product to be light in color and of glossy appearance.

The grapes are dried in the sun, as previously described for lye-dipped Sultanina grapes.

Bleached Sultanina Raisins.—There is a considerable demand among the Jewish population of the eastern United States for bleached seedless raisins, prepared by exposing lye-dipped Sultanina grapes to the fumes of burning sulphur for 3 to 5 hours before spreading in the dry yard. Drying is conducted as described for the soda-dipped raisins.

A perfect specimen of bleached Thompson Seedless raisins should be translucent and white to very light amber in color. It should be dried sufficiently so as not to exude syrup when pressed between the fingers but should be tender, not brittle or tough. The flavor of the bleached raisins is not as pleasing as that of the unsulphured fruit.

The yield of dried fruit per acre of bearing vineyard is, in northern California, about 1½ to 3 tons.

Drying Grapes in Australia.—The process of drying grapes in Australia is described as follows by H. F. Levien, a prominent grape grower of Renmark, South Australia.

The following classes of raisins are produced: currants, Sultanas (lye-dipped), Muscats, not dipped and Muscats lye-dipped. Lye-dipped Muscats are known as "lexias," an adaptation from the Spanish.

Racks.—At one time raisins were made by sun drying on 2- by 3-foot trays, as in California, but owing to the heavy losses from rains and to the labor cost of stacking trays in inclement weather, a process peculiar to Australia has been developed. The grapes are dried on wire netting racks beneath a sheet metal roof or wooden shed. Wire netting of 2-inch mesh and 18 gage is "strung," *i.e.*, fixed to heavy 6-gage wire to give it rigidity and is fastened to posts by fixed or removable frames. Six or more tiers of the netting are used one above the other.

Currants are spread on the screens without dipping. Muscats (Muscat Gordo Blanco) and Sultanas (a seedless grape) are usually dipped in a dilute boiling lye solution and rinsed before spreading on the netting racks. A perforated metal bucket is used in spreading dipped grapes. Lug boxes are used for currants, as these are not lye-dipped.

Drying Time.—The fruit is not exposed to the sun, but is dried by air currents which circulate freely between the racks. Currants require 14 to 21 days for drying, lye-dipped Sultanas about 10 days

and Muscats about 14 days. Undipped Muscats and Sultanas require considerably longer periods.

Quality.—The color of raisins dried on racks is very attractive, is lighter than that of raisins prepared by sun drying, often some of the green color of the fresh grapes being retained and the flavor is excellent.

Yields.—The average yield of Muscat raisins per acre is about 1 ton, of Sultana about 1,800 pounds and of currants about 1½ tons. With improved methods of cultivation and care it is possible to double the average yields.

The Australian raisins are marketed principally in England, New Zealand and in Australia, but increasing production will undoubtedly force the growers to seek additional markets.

Association.—The dried fruit producers of Australia are organized under the name of the Australian Dried Fruit Association and use the trade mark "Sunraysed."

The Sun Drying of Wine Grapes and Cull Table Grapes.—Since the passage of the Eighteenth Amendment to the federal Constitution of the United States there has been a demand for dried wine grapes for the preparation of home-made beverages. Wine grapes, principally of the red wine grape varieties, have been dried on an extensive scale in the raisin districts of California without previous treatment, by the same methods now in use for the drying of Muscat and Sultanina grapes. Sun-dried grapes produced by this method yield on soaking in water a juice of dark brown, not red, color, while consumers of these grapes desire a red juice for beverage purposes. In experiments made at the University of California Farm, it was found that the red color could be retained by dipping the grapes in lye and exposing the dipped grapes to the fumes of burning sulphur for about 1 hour before drying. Wine grapes require a 2 to 3 per cent lye solution for satisfactory checking of the skins.

Until a few years ago cull table grapes from the fresh fruit packing houses were utilized for the manufacture of wine and brandy. They are now dried in the sun or in dehydraters after lye dipping and have found a ready market as cheap raisins.

THE SUN DRYING OF FIGS

Smyrna has long been known as the world's principal fig exporting port. The fruit is produced in Palestine and other districts of western Asia Minor. In recent years the production of dried figs in California has rapidly increased and California is now Smyrna's strong competitor in the markets of the United States.

Varieties of Figs for Drying.—The "*Smyrna*" fig (more properly, Lop Injir), a large white variety, is the principal variety grown in the Mediterranean countries for drying. It requires fertilization with the

pollen of some other variety, accomplished by a small wasp which develops inside a male variety of fig grown for pollination purposes and known as the capri fig; on emergence from the later the insect carries on its legs and body pollen from the flower of the capri fig, the flowers of which are borne inside the fig. The insect, known as *Blastophaga grossorum*, escapes through the small opening in the blossom end of the capri fig, enters the eye of the immature Smyrna fig and pollenizes it. The Smyrna fig does not develop or ripen unless pollenized in the manner described above. The capri fig remains on the tree during the winter and serves as an abode for the *Blastophaga*, a fact which prevents extermination of the insect after the removal of the figs from the Smyrna trees.

The Smyrna variety is large, of excellent flavor and is attractive in appearance when packed. An objection to this variety when grown in a cool climate is its tendency to ferment and sour before drying.

"Calimyrna."—A strain of the Smyrna variety is grown in California under the name of "Calimyrna." Its successful culture has been made possible by the studies of George Roeding of Fresno and G. P. Rixford of the U. S. Department of Agriculture.

Adriatic.—The Adriatic fig is a white variety of pink flesh. It requires no artificial pollenization and a large proportion of the seeds are sterile. It is inferior in size and flavor to the Calimyrna variety, but is a heavy bearer and is grown extensively on that account.

Kadota.—The Kadota (according to Coit and Condit,[11] the Dodatto) is a white variety now planted extensively in California for fresh shipment and for canning and preserving. It is on the average smaller in size than the Calimyrna and Adriatic varieties and requires no pollenization. It is the most satisfactory variety grown in California for canning and preserving, because of the fact that the walls of the fruit are thick and the seed cavity is small. A limited quantity only of the fruit is dried.

Mission.—The Black Mission fig which has been grown in California since the days of the early Spanish mission, yields a dried product of black color, tender texture and excellent flavor. The fig is not subject to souring or black smut and the trees yield heavily. The dried product is used with the white varieties for fancy mixed packs.

Harvesting.—Figs should not be picked for drying, but should be allowed to ripen and partially to dry on the tree and fall to the ground of their own accord. If picked from the tree the fruit is liable to sour on the trays or mold and the dried product will be woody and of poor flavor. The orchard ground should be made as smooth as possible by rolling.

The fruit should be picked from the ground frequently and should not be allowed to lie on the ground more than 2 or 3 days because of danger of molding of certain varieties, toughening of the skin of other varieties

and danger of infestation with insects which gain entrance through the eye of the fig.

Dipping and Sulphuring.—Calimyrna figs are in some dry yards dipped in a solution of 10 pounds each of salt and hydrated lime per 100 gallons of water in order to remove some of the hairs from the surface, to improve the color and to soften the skins. Some Adriatic figs are also dipped in a solution of the above or similar composition. Mission figs are not dipped before drying.

The figs are carefully sorted as they are spread on the trays and the Adriatic figs are usually sulphured, in order to bleach the flesh and to sterilize them. It is believed that sulphuring checks fermentation and destroys insects and insect eggs. The trays are usually placed in the sulphur box in the evening and allowed to remain in the fumes of the burning sulphur overnight, 3 hours or more sulphuring being necessary to accomplish the desired results. The Calimyrna fig should not be sulphured except under adverse drying conditions to prevent souring.

Drying.—As they arrive at the dry yard figs are usually from one-half to two-thirds dry. On this account it is frequently possible to stack the trays immediately after spreading the fruit and to accomplish most of the drying in the stack. Exposure to the sun toughens the skin of the Calimyrna variety and a dried product of better quality is obtained by drying the fruit entirely in the stack.

The figs are dried until firm and until juice or syrup can no longer be expressed with the fingers.

Sorting and Boxing.—The dried fruit is carefully sorted on the trays to remove bird-pecked, green and split fruit and fruit showing evidence of smut. The cull fruit is of little value except for hog feed. In some yards the Adriatic figs are dipped in salt solution after drying and are sulphured before being placed in sweat boxes. Most of the fruit is, however, placed directly into sweat boxes from the trays. Figs should not be placed in sacks, as such treatment is liable to result in crushing of the fruit and in injury to its appearance.

Harvesting and Drying Figs in Asia Minor.—Roeding[8] has briefly described the harvesting and drying of Smyrna (Lop Injir) figs in the following manner.

Harvesting.—Before harvesting begins the orchards are weeded carefully so that the figs may be seen readily after they have dropped. The harvesting season begins about Aug. 5, but the best fruit is gathered in September.

The figs drop to the ground and are gathered in baskets holding about 50 pounds when filled, but the baskets are gathered only half full.

Dry Yard.—The drying ground is usually an open space in the orchard where a few trees have died and have not been replanted. Layers of rushes about 2 inches thick and about 3 feet wide with pathways

between them are prepared. The figs are dumped from the baskets on the rushes and are then spread by hand one layer deep.

The figs are stirred daily with the hands and the small figs, which dry first, are removed. The usual length of the drying period is 2 to 4 days.

Storing.—The dried figs are usually stored in a small room in the dwelling of the owner or foreman. At the end of the season they are sorted into three grades for size and are packed in goat hair sacks for shipment to the packing house.

None of the figs are packed in the fig growing districts, but are shipped to Smyrna and packed in special establishments for this purpose.

DATES

Dates require a hot, dry climate and an abundance of water supplied naturally or by irrigation. The Valley of the Nile, Tunis and Algeria and the oases of the Sahara and Arabian deserts supply these necessary conditions and have since the beginnings of civilization been the world's principal source of supply for this fruit.

Varieties.—The most important variety grown in Arizona and California is the Deglet Nur (Deglet Noor in California) more properly, according to Popenoe,[13] the Daqlet al Nur. This variety is grown extensively in Algeria and Tunisia. It is of medium size, mild flavor and, if properly cured, is of light amber color and translucent. Other important varieties are the Ghars, a very large early maturing variety, the Kasbeh, a good shipping date, the Khadrawi, from the Persian Gulf and successfully grown in California, and the Halawi, an Arabian variety. The fruit of the most desirable varieties is large, of good flavor, tender texture and of good packing and shipping quality. Varieties that mummify or sour or ferment on the trees or become very soft and syrupy after packing are not desired.

Harvesting.—A few varieties ripen in California in July, but the principal harvesting season is in September, October and November. The fruit is borne in large bunches on the end of a tough stalk, which is bent downward in the form of a bow from the weight of the fruit.

Ripening on Tree.—Unripe dates are green in color and very astringent owing to their high content of tannin. During ripening the tannin disappears to a large extent, the color of the date becomes brown, red or amber and the flesh becomes soft, syrupy and translucent.

Some varieties tend to dry on the tree to a leathery texture instead of to the usual desirable soft texture. This "mummifying" can be prevented by irrigation during ripening.

It is sometimes necessary to cover the bunches with cheesecloth bags to exclude birds and insects.

Early rains may cause souring of the dates or make it necessary to harvest them unripe and to ripen them artificially.

According to J. E. Coit,[7] the usual methods of harvesting dates in the southwestern United States are as follows:

> *Picking and Fumigating.*—In the Coachella Valley in California the weather is usually so dry during ripening time that the fruit loses moisture as it matures and mummifies on the trees, becoming like dry bread dates. While dry Deglet Noors are quite appetizing, the market demands them soft and translucent, the condition in which imported Deglet Noors reach this country. In one large plantation the dates are picked every 3 days, selecting those which are completely ripe but before they have hardened. They are then fumigated in a cabinet with carbon disulphide, ½ ounce to the cubic foot, for 2 hours to sterilize the fruit and kill any insect eggs which may be present.
>
> *Ripening.*—The fruit is then placed in specially made tight wooden boxes. The boxes are then placed in an ordinary poultry incubator and kept from 3 to 5 days at about 96°F. The chemical reactions taking place in the dates during this time may possibly result in water being formed, for the dates go in dry and firm and come out soft, moist and beautifully translucent with a delightful aroma, which is characteristic of the Deglet Noor. The dates are then graded and packed in fancy 1-pound boxes. A temperature somewhat below 100°F. for several days seems to give better results than a higher temperature for a shorter time.

In some groves the dates ripen sufficiently on the trees and can be packed without ripening at 100°F as described above.

> *Packing.*—After being sterilized by fumigation, as above explained, they are placed in a drier and the excess moisture quickly driven off. They are then sorted into grades, the best being carefully packed in fancy confectionery boxes. The second grade is packed in bulk in 50-pound wooden candy tubs, or utilized for by-products. As explained before, it is essential that the varieties handled in this way have a high sugar content. If they are low in sugar they shrivel when dried sufficiently to keep indefinitely without fermentation.

Insect Injury.—In Arizona a small brown beetle (*Carpophilus dimidiatus*) works its way under the skins or into the opening at the base and lays eggs which hatch later into grubs which accelerate souring. In California the same insect together with the Indian meal moth (*Plodia interpunctella*) has proved very troublesome. All packing rooms should be thoroughly screened and after pasteurization or fumigation the dates should not leave the screened room until packed. It is important to see that the containers are insectproof.

Glass-packed Dates.—Deglet Noor and similar varieties are now also packed in glass jars without previous drying. The product is moist and possesses the rich flavor of the fresh date.

The dates are allowed to ripen on the tree or on the bunch after removal from the tree. They are picked carefully and are not dried before packing. They are packed into glass jars which are heated to 165°F. and sealed under vacuum, no further processing being necessary.

SUN DRYING OF APRICOTS

Although most of the dried apricots consumed in America are produced in California, this fruit is also dried commercially in France, Australia and Asia Minor. It has been an important article of diet in Asia Minor for many centuries.

Varieties.—In California the Royal, Blenheim and Moorpark are the principal varieties used for drying. The Tilton, Hemskirk and Peach varieties are grown in limited quantities only. The above varieties are described in the chapter on fruit canning.

In the coast counties of central California (Santa Clara, Alameda, Napa, San Benito and Sonoma counties) the Blenheim is preferred to all other varieties. In southern California and in the hot interior valleys the Royal is the principal variety used for drying.

Harvesting.—The fruit should be allowed to remain on the trees until "eating ripe," that is, somewhat riper than for canning purposes. Apricots should be picked frequently, so that the fruit shall be neither too ripe nor too green since under-ripe fruit yields a badly shriveled, tough dried product of poor flavor and over-ripe fruit forms "slabs" during drying. Slabs, while of excellent flavor and color, are of unattractive form and must be sold at a low price.

Cutting and Traying.—The fruit in the lug box is placed beside the cutter on a level with the tray, or part of the box may be dumped on the tray. Fruit and empty trays are brought to the cutters and filled trays are removed by men or boys assigned to these duties. The cutters' only duties are to cut the fruit in half around the suture, remove the pits and spread the cut halves on the trays with cups upward. The knife should be run completely around the fruit to the pit, in order to give smooth edges to the cut fruit. Cutters average from 600 to 1,200 pounds per day and the cost of cutting varies from $5 to $7 per ton.

In most yards trays are 8 by 3 feet in size, and the fruit is spread one layer deep. Each square foot of tray surface will hold about 2 pounds of cut fruit.

The pits are placed in lug boxes and are later spread on trays and dried in the sun for sale to by-product factories.

Sulphuring.—The filled trays are stacked on dry yard cars and placed in a sulphur box, where the fruit is exposed to the fumes of burning sulphur at least 3 hours. The last cars to enter the sulphur houses in the afternoon remain overnight. The fruit should be sulphured until the cups fill with juice.

Approximately 8 pounds of sulphur per ton of fruit are normally required but the length of exposure to the fumes is, however, far more important than the weight of sulphur used.

Properly sulphured apricots should not turn brown during or after drying and should retain the clear golden yellow of the fresh fruit. Sulphuring does not bleach the carotin pigment of the apricot, but merely prevents darkening of other pigments.

Drying.—The apricot ripens in July and early August in California, *i.e.*, in midsummer; consequently no difficulty is experienced in obtaining sufficient sunshine for drying the fruit.

The trays are spread in the sun for 1 to 4 days, which intensifies the golden color of the fruit and changes green fruit to a golden yellow color, in addition to causing drying.

When the fruit is one-half to two-thirds dry the trays are stacked in such manner that the prevailing wind may pass freely between them.

Properly dried apricots should be soft and pliable, but not sticky, and when a handful of the fruit is squeezed it should not stick together when the pressure is released. When an individual piece is pressed between the fingers, it should not be possible to obtain juice or syrup. On the other hand, the fruit must not be overdried. It should contain about 18 per cent moisture.

Sorting, Boxing and Sweating.—When most of the fruit is sufficiently dry it is carefully sorted, slabs being placed in a separate box, fruit which requires further drying being returned to the trays and the properly dried fruit scraped from the trays with wooden paddles or steel scrapers into lug boxes.

The dried apricots are stored in bins or in heaps on a wooden or concrete floor to undergo sweating for several weeks before packing or delivery to the packing house. Sacks are usually employed as containers for delivery of the fruit.

Yields and Costs.—According to a survey of a number of California dry yards made by Christie and Barnard[1] of the University of California, the average cost of harvesting and drying for 1920 and 1921 was $80 per dry ton in 1920 and $88.94 in 1921.

In large, efficiently operated dry yards these costs can be reduced; in small inefficiently operated yards the costs will be greater. The costs and yields also vary considerably from year to year and with the locality.

Unpitted Dried Apricots.—Occasionally very small apricots are dried whole without cutting in half or pitting. The fruit is first dipped in lye as described elsewhere for prunes, is then sulphured 6 to 10 hours and dried in the sun in the usual manner. The product is satisfactory for preparing and serving in the same manner as dried prunes but the market is limited.

Apricot "Leather."—In Asia Minor ripe apricot pulp is dried in the sun to a leathery consistency in the form of sheets, which are then rolled for convenience in packing. The "leather" is eaten as a confection or is cooked in the form of a sauce.

SUN DRYING OF PEACHES

Most of the sun-dried peaches of California are sold through a cooperative association known as the California Peach and Fig Growers' Association, under the "Blue Ribbon" brand.

Australia and South Africa are increasing their output of sun-dried peaches and are following California methods of drying and marketing.

Varieties.—A peach suitable for sun drying should be a freestone variety of large size and high sugar content. It should be pulpy, rather than juicy, with flesh of rich golden yellow color and of pleasing flavor.

The Muir peach most nearly fulfils these requirements and more than 60 per cent of the dried fruit produced in California is of this variety. The Lovell is second in importance to the Muir. Other important varieties are the Crawford, Foster, Salway and Elberta. One of the principal objections to the Elberta is the red color of the pit cavity.

Clingstone varieties cannot be pitted economically and give a low yield of dried product because of their low sugar content.

Harvesting.—Peaches should be picked when they have become slightly soft to the touch over the entire surface. They are firmer than apricots but when bruised, even slightly, the flesh darkens quickly. They must, therefore, be handled with great care and should be cut and spread on trays as soon after picking as possible.

Several pickings should be made during the season in order to insure a dried product of highest quality. Although much of the fruit is knocked with poles or shaken from the trees, this method should not be used, because it not only results in bruising the fruit but removes a large proportion of green fruit, which gives a dried product of unattractive gray color, poor flavor and woody texture.

Cutting, Traying and Sulphuring.—The cutting and traying operations are conducted as described elsewhere for apricots, the cost of pitting being less because of the larger size of the fruit. The halves are placed with cups upward on trays 8 by 3 or 6 by 3 feet in size.

Peaches are sulphured 4 to 6 hours or overnight. A longer period of sulphuring is required than for apricots because of the larger size of the halves.

Clingstone peaches are cut to the pit longitudinally into four segments but are not pitted. They must be sulphured at least 12 hours.

Drying and Sweating.—The method of drying is identical with that described elsewhere for apricots, although the drying period is somewhat

longer. As much of the drying should take place after stacking as possible, in order to obtain a dried product of highest quality.

A well-dried peach should be golden yellow, not gray-green or brown, and firm and pliable, but not syrupy or sticky.

The fruit is sorted on the trays after drying and placed in sweat boxes, bins or in piles on the floor to undergo sweating before delivery to the packing house. The fruit continues to lose moisture during this storage period.

The usual drying ratio is about 4½:1 but will vary from 3.5:1 to 7:1 according to the variety and its maturity. The Muir and Lovell varieties yield more heavily than the Elberta.

Costs.—Christie and Barnard[1] have collected data on drying costs for the years 1921 and 1922 in California. Their averages are: cutting cost $3.34 to $3.46 per green ton, dry yard labor $1.33 per green ton and total cost of picking and drying, $13 per green ton.

THE SUN DRYING OF PEARS

The Bartlett pear is the most important variety grown commercially for sun drying, but dried pears are very much less important than dried apricots, prunes, figs and raisins.

In most pear growing sections of California the pears used for drying are the culls from fresh fruit packing houses and canneries. In Lake County in California, however, because of lack of transportation facilities almost the entire crop is utilized for drying.

Harvesting.—Bartlett pears are harvested while still too green for eating and are allowed to ripen after picking. If to be used for drying and not for fresh shipment, the fruit should show beneath the background of green a faint to pronounced yellow color, but should still be too firm for eating fresh.

Ripening and Sorting.—Cull pears are usually placed on straw in rows about 1 foot wide and 6 inches deep and covered with straw. As the fruit ripens it is sorted two or three times. Usually a week to 10 days is required for ripening, although wormy and sunburned fruit will ripen in less time.

In Lake County the fruit is allowed to ripen in lug boxes stored beneath a shed and is sorted frequently, in order to obtain prime ripe fruit.

The loss in sorting amounts to 3 to 25 per cent, depending upon the quality of the fresh fruit and frequency of sorting.

In some of the large dry yards the pears are graded for size by a mechanical grader before ripening. Large pears require a longer period of drying than small ones, hence the desirability of placing on each tray fruit of uniform size.

Cutting and Traying.—The pears are cut when they have become "eating ripe," but before they have become "mushy." Over-ripe fruit produces slabs, while under-ripe gives a dried product of woody texture and poor flavor.

The fruit is cut in half lengthwise, but is not peeled. In most dry yards the stem and calyx are removed but the fruit is not cored.

The pears are spread with the cut surface upward on trays 8 by 3 feet in size.

Sulphuring.—The fruit and trays should be thoroughly sprinkled with water before they enter the sulphur house, in order to facilitate absorption of the sulphur dioxide. In some yards the cut fruit is dipped in or sprinkled with dilute brine, as salt retards darkening.

In Sacramento and Contra Costa counties, where cull pears are used, the fruit is sulphured from 8 to 24 hours and in Lake County 48 to 72 hours. A pear properly sulphured before drying is very soft throughout, since sulphuring softens the tissue very markedly. The market demands a dried pear that is very light in color and nearly transparent, a condition that can only be obtained by the excessively long periods of sulphuring noted above.

Drying.—In the method used in Lake County, California, the pears are spread in the sun for from ½ to 2 days. The trays are then stacked beneath long sheds open at the sides and so placed that air may circulate freely between the trays. Three to 6 weeks' time is required to complete the drying process, the slow drying in the shade in this manner producing a dried pear that is nearly transparent and very attractive in appearance.

In the "Contra Costa County process" the pears are spread in the sun until one-third to two-thirds dry before the trays are stacked. Drying is accomplished in a shorter time than in the Lake County process, but the dried product is less translucent and is of darker color.

Because of heavy sulphuring, dried pears do not undergo molding or fermentation readily and need not be dried to as low a moisture content as peaches or apricots before removal from the trays. A properly sun-dried pear should be pliable, of tender texture, light color and should be translucent. A chalky-white or brown color is not desired by the trade.

MISCELLANEOUS FRUITS

Cherries.—Split, over-ripe and rain-damaged cherries are dried in the sun to a limited extent in California.

Preparation of cherries for sun drying consists in dipping the fruit in a boiling dilute lye or sodium carbonate solution to check the skins. White cherries, such as the Royal Anne, are improved in appearance if sulphured for about 1 hour after lye dipping. Black varieties need not be sulphured. Drying is conducted as described elsewhere for prunes.

Berries.—Raspberries, strawberries and loganberries are frequently sun dried for home use. The untreated fruit is spread on wooden trays in the sun until about two-thirds dry. Drying is then completed after stacking the trays. L. C. Barnard, of the University of California, has found a dried product of improved color and flavor is obtained if the fresh berries are sulphured for about 1 hour before drying.

All berries are of much more attractive appearance and better cooking quality if dehydrated.

Persimmons.—The Japanese dry large quantities of persimmons, which are used as a confection and food. The ripe fruit is peeled and threaded on strings which are hung in the shade until the fruit is dry.

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CHAPTER XXI

THE DEHYDRATION OF FRUITS

As the Civil War of America in the sixties stimulated the canning industry, the Boer War and the World War stimulated the dehydration industry. To conserve cargo space and transportation facilities, enormous quantities of foods were dehydrated during the World War and shipped to the allied armies in Europe.

In Germany in 1898 there were, according to Prescott,[1] only three drying plants. In 1917 the number had increased to about 1900, a fact which explains in part Germany's ability to maintain her food supply during the war.

The dehydration of fruits has become a well-established and growing industry. Apples have been dehydrated (or "evaporated") in America for at least a century and the dehydration of prunes in the Pacific Northwest is an old and very important industry.

Definitions.—*Dehydration* is at present defined industrially as drying by artificially produced heat under carefully controlled conditions of temperature, humidity and air flow. To dehydrate means to remove water.

The term *dried* is applied to all dried products, regardless of the method of drying.

Evaporation is usually considered industrially to mean drying under conditions of humidity, temperature and air flow not so carefully controlled as in dehydration. Evaporation is a broader term than dehydration. If applied literally, the evaporation of fruit would mean the complete vaporization of the whole fruit, both water and solids. Alcohol, ether and other liquids, as well as water, may be evaporated.

Dessication is essentially equivalent in meaning to dehydration.

The terms *drier*, *dehydrater* and *evaporator* are at present used more or less indiscriminately, although the term "drier" is often considered to be a general one applicable to all types of drying apparatus and a dehydrater is often considered to be more efficient and to permit of more exact regulation than an evaporator.

Relative Merits of Sun Drying and Dehydration.—At the present time most dried fruit is dried in the sun by the methods described in Chapter XX, but dehydration is rapidly increasing in importance, because of its following advantages: (1) Dehydrated fruits, when cooked, more nearly resemble the cooked fresh fruit in flavor and color than do cooked

sun-dried fruits. (2) They are generally produced under more sanitary conditions than sun-dried fruits. (3) Dehydration permits of more careful control of the quality of the finished product. (4) Less land and fewer trays are required for dehydration than for sun drying. (5) In seasons of early rains, the use of dehydraters prevents loss through rain damage.

Relative Cost.—Dehydration has usually been somewhat more costly than sun drying, but undoubtedly the superior cooking quality of the dehydrated products will cause them to command a sufficiently higher price to more than counterbalance the slightly greater cost of production.

Relative Yields.—Dehydration usually gives a somewhat higher yield of dried product (calculated to a common moisture content) than is obtained by sun drying, even under ideal sun drying conditions. This difference is due probably to loss of sugar in sun drying through respiration or fermentation. During cloudy or rainy weather loss of sugar in sun drying through fermentation becomes excessive.

For the small orchardist the cost of sun drying trays is usually less than that of a dehydrater, but for the large operator the cost of the dehydrater may in some cases be no more than that of sun drying trays. Costs of construction will be discussed in greater detail later in this chapter.

Color.—During sun drying of green or slightly immature cut fruits, such as peaches and apricots, the fruit acquires the color of the fully mature fruit. In dehydration the fruit retains the color possessed at the time of cutting, fruit of green color retaining this color after dehydration. It is, therefore, essential that fruit used for dehydration be fully mature.

Cooking Quality.—The dehydrated fruits in all cases are superior to the sun-dried for cooking purposes, although not always equal to or superior in appearance before cooking. Comparison should be made of the refreshed and cooked fruits rather than the dried fruits.

PRINCIPLES OF DEHYDRATION

A thorough knowledge of dehydration is not possible without an understanding of the fundamental physical and chemical principles involved.

Advantages of Air As a Drying Medium.—Foods may be dried in (1) air, (2) in superheated steam, (3) in vacuo, (4) in inert gases or (5) by direct application of heat. Air, however, is the usual medium employed industrially for the following reasons: It is cheaper and more convenient to install and operate dehydraters using air as a drying medium. Where air is used, overheating is avoided. Air can be used to conduct heat to the product to be dried and to conduct the liberated moisture from the

product undergoing drying. No elaborate or costly moisture condensers are required when air is used as the drying medium. The use of air permits gradual drying and thus avoids loss of juice by dripping. It also reduces the tendency for fruits to discolor and scorch.

Functions of Air in Drying.—Air has two principal functions in the drying of fruits or other foods. It conveys heat from the furnace room or other heating device to the product and thereby causes the water in the product to vaporize, and also serves as a vehicle for the transfer of moisture to the outside atmosphere. Both functions are important and necessary.

Relative Volumes of Air for Heat Conductance and Transportation of Water Vapor.—A larger volume of air is required to conduct heat to the drying chamber than to transport water vapor from the drying chamber, as illustrated in the following discussion.

For example, if dry air enters the drying chamber at 150°F. and leaves at 110°F. (a drop of 40°F.), approximately 1,750 cubic feet of air are required to furnish enough heat to evaporate 1 pound of water, while at 110°F. only approximately 235 cubic feet of air (dry on entry to the dehydrater) are required to transport 1 pound of water vapor. The ratio of air required to remove liberated moisture is in this case about 7:1.

If, however, the entering air is not perfectly dry, or if the escaping air is not saturated, the ratio becomes lower.

Since more air is required for transportation of heat than for transportation of moisture, the former amount must be used in calculating the air requirements of a given dehydrater.

For simplicity, the above calculations disregard the slight differences in volume of air caused by differences in temperature, and slight differences in the specific heat of air occasioned by differences in relative humidity. Increase in temperature increases the volume of air in accordance with the law of Gay Lussac, *i.e.*

$$V = V_o\,(1 + 0.003665t)$$

where V = volume at temperature (t) and V_o = volume at 0°. The formula is based on Centrigrade temperature.

Expressed in a different manner, the volume of any gas maintained at constant pressure increases $\frac{1}{273}$ in volume for each 1°C. rise in temperature. For this reason it is often convenient to express air measurements in terms of weight, *e.g.*, as kilograms or pounds, which can, when desired, be converted into cubic meters or cubic feet.

Necessity of Heat.—It should be borne in mind that it is heat that produces evaporation and not the air nor any mysterious property assigned to a vacuum. Approximately 1,000 British thermal units of heat are required to change 1 pound of water to vapor and this figure is known as the latent heat of vaporization of water. The latent heat of vaporization will vary somewhat with the temperature at which evaporation occurs, but

at the temperatures used in the drying of fruits and vegetables an average of about 1,000 British thermal units may be taken for purposes of calculation of air requirements, etc. A British thermal unit (1 B.t.u.) is the amount of heat required to raise the temperature of 1 pound of water 1°F. Table 45 gives the relation of temperature of evaporation to heat required for the evaporation of 1 pound of water.

These amounts are required regardless of whether the product from which the water is evaporated undergoes boiling or not. The mere fact that heat is conducted to the product by air, and evaporation of the moisture from the product occurs without boiling, does not alter the amount of heat required for evaporation.

It is possible to dry fruit or other materials with air at atmospheric temperatures without previously heating the air. In this case the air will drop in temperature, and if this fact and the weight of the air are taken into account it will be found that the evaporation process has taken the normal number of heat units and that the air possesses no miraculous power of "absorbing" moisture without the use of heat. Heat in this case comes from solar energy, since the atmospheric air has been heated by the sun's rays.

Volume of Air Required.—The volume of air required for the evaporation of 1 pound of water will vary greatly with the temperature at which evaporation takes place, because of expansion in volume with increase in temperature. If the calculations are, however, based upon the weight of the air and only the final results expressed in volume, calculations are greatly simplified. In most dehydraters all of the heat required for the evaporation of moisture is obtained from heated air, the work done in evaporating moisture causing a drop in temperature of the air. This drop is a function of the amount of moisture evaporated and can be calculated if the other conditions are known.

Ridley[2] has calculated the air requirements for a typical tunnel, air-blast dehydrater as follows:

One cubic foot of air at 60°F. requires 0.01807 B.t.u. to increase its temperature 1°F., and conversely 1 cubic foot of air dropping 1°F. will release 0.01807 B.t.u. of heat.

Condition in Tunnel Dryer.—If we assume a condition in which the air enters the dehydrater at 60°F. and is heated to 160°F., at which temperature it enters the tunnel, and is exhausted from the dehydrater at 120°F., the temperature drop will be 40°F.

The heat required to evaporate 1 pound of water at 60°F. is 1,058 B.t.u., and to heat 1 pound of water from 60 to 160°F. and evaporate this amount of water at the higher temperature is 1,102 B.t.u., the heat units necessary decreasing with rise in temperature. Assuming a mean value of 1,080 B.t.u., the number of cubic feet of air required will be

$\frac{1,080}{0.01807}$, or approximately 60,000 cubic feet dropping 1°F., equivalent to $\frac{1,080}{0.01807} \div 40$ or 1,500 cubic feet of air dropping 40°F. This is assuming that the air is measured at 60°F. If it is measured at 160°F., a much larger volume is required because of the expansion of the air through rise in temperature. Thus 1,500 cubic feet at 60°F. becomes 1,805 cubic feet at 160°F. The volume at any other temperature can be calculated by Gay-Lussac's law.

In addition to the heat required for the evaporation of water, heat is required for heating the trays, cars and tunnel walls to the temperatures used during drying.

Air Requirements for Prunes.—Assuming that the dehydrater holds 10 tons of fruit and it is desired that the fruit be dried in 24 hours under the temperature conditions noted above, and the drying ratio of the fruit is 2½:1 (*i.e.*, 2½ pounds of fresh fruit yields 1 pound dry), the amount of moisture to remove per 24 hours is 12,000 pounds, or 8.3 pounds per minute. With a temperature drop of 40°F., there will be required 8.3 × 1,500, or 12,450 cubic feet per minute. This is a minimum requirement and does not take into account losses of heat by radiation and leakage and that required to heat the cars, trays, etc., to the temperature of the dehydrater. Experience has proved that this quantity should be increased in actual commercial practice to at least 15,000 cubic feet per minute, and preferably to 20,000 cubic feet per minute, in order to dry the fruit in the required time of 24 hours.

Other Fruits.—Apples, peaches, apricots and most other fruits possess drying ratios of 5:1 or 6:1. Therefore, the air requirements will be considerably larger for these other fruits than for prunes. With a drying ratio for apples of 6:1 and a drying time of 10 hours it would be necessary to remove 16,666 pounds of water per 10 hours, or 27.7 pounds per minute. This would require, with a temperature drop of 40°F., not less than 41,500 cubic feet per minute. In a similar manner the air requirements for other fruits or for other temperature conditions can be calculated.

Air Velocity.—In dehydraters tested in California in 1920 and 1921 it was found that the air velocity varied from less than 20 feet per minute to nearly 1,000 feet per minute. The velocity was measured by means of an anemometer, an instrument equipped with a small disc type fan, as shown in Fig. 79.

Air velocity can also be determined from measurement of the air pressure in the drying compartment by means of a Pitot tube. A description of this instrument will be found in this chapter in the section on static pressure.

Velocity Equation.—It has been found that the rate of evaporation of water from a free surface is directly proportional to the velocity of the air, other things being equal. This relation may be expressed by the following equation (according to Carrier[10]):

$$W = 0.093\left(1 + \frac{v}{230}\right)(e' - e)$$

where W = pounds evaporated per square foot per hour.
v = velocity of air over surface in feet per minute.
e' = vapor pressure of water corresponding to its temperature.
e = vapor pressure in the surrounding atmosphere.

Thus at an air velocity of 230 feet per minute, drying is twice as rapid as in still air, and at 460 feet per minute it is three times as fast as in still air.

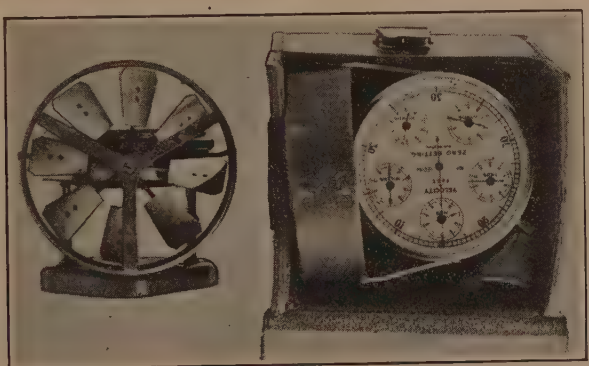

Fig. 79.—Anemometer for measurement of air flow in dehydraters.

Velocity in Commercial Dehydraters.—In practice it has been found by observation that velocities above 300 feet per minute and not in excess of 1,000 feet per minute should be used in air-blast dehydraters. At velocities above 1,000 feet per minute static pressure and the power necessary to operate the fan become so great that additional increase in velocity is apt to become uneconomical. It is also true that evaporation from the surface of fruits and vegetables is slower than from a free surface, such as a wet lamp-wick, and that the Carrier equation does not apply well in high air velocities.

The velocity of air required will vary with the distance between trays and the load on the trays. A convenient way of expressing air requirements for dehydraters is in terms of cubic feet of air per minute per square foot of tray surface. For an air-blast dehydrater, this number should not be less than 250 cubic feet per square foot of drying surface.

Measurements of air velocity and drying times for various fruits obtained in the study of dehydraters in California are given in Table 59. (Compare F and N particularly.)

TABLE 59.—EXAMPLES OF AIR-FLOW MEASUREMENTS AND DRYING TIMES

(*After Cruess and Christie*)

Plant	Type of dehydrater	Fruit	Velocity of air across trays, linear feet per minute	Total volume of air, cubic feet per minute	Volume of air per 100 square feet of tray surface, cubic feet per minute	Approximate drying time, hours
F	Air-blast direct heat.......	Grapes	424	20,800	290	24
C	Air-blast direct heat.......	Grapes	485	15,800	275	24
A	Air-blast direct heat.......	Prunes	510	44,000	255	24
O	Air-blast tunnel batch type	Grapes	450	17,500	250	18–24
E	Air-blast tunnel type.....	Grapes	265	8,600	250	18–30
G	Air-blast direct heat.......	Grapes	197	7,486	235	22
B	Air-blast tunnel type.....	Prunes	357	11,390	200	30
M	Stack-type gravity air flow	Prunes	Less than 20	4,500	130	30
M	Stack-type gravity air flow	Prunes	Less than 20	4,800	100	36
N	Ceramic oven.............	Grapes	Less than 20	6,017	110	80

Effect of Humidity and Temperature.—Tiemann[8] in his bulletin on the theory of drying gives the relation between the temperatures and humidities of the ingoing and outgoing air, the volume of air required and the heat units required to evaporate 1 pound of water, as shown in Table 60.

TABLE 60.—RELATION OF TEMPERATURE AND HUMIDITY OF AIR TO VOLUME OF AIR AND HEAT UNITS REQUIRED TO EVAPORATE 1 POUND OF WATER

(*After Tiemann*[8])

Entering air		After heating		Leaving air		Heat consumed to evaporate 1 pound of water from initial temperature of 59°F.	Total heat of 1 pound of vapor at t_3 above initial temperature of 59°F.	Minimum volume of air required	Efficiency H ÷ G
t_1	h_1	t_2	h_2	t_3	h_3				
A, °F.	B, Per cent	C, °F.	D, Per cent	E, °F.	F, Per cent	G, B.t.u.	H, B.t.u.	J, Cubic feet	K,
32	100	95	11	65.0	75	2,353	1,074	2,163	0.457
59	100	95	31	76.0	75	2,100	1,078	3,426	0.514
32	100	158	2	84.0	75	1,911	1,080	993	0.565
59	100	158	6	92.0	75	1,715	1,082	1,126	0.631
86	100	158	13	107.0	75	1,556	1,087	1,402	0.698
32	100	212	0+	97.0	75	1,758	1,084	694	0.617
59	100	212	2	103.0	75	1,572	1,086	731	0.690
86	100	212	4	114.0	75	1,422	1,089	796	0.767
32	100	95	11	84.0	25	6,136	1,080	5,738	0.176
32	100	158	2	110.0	25	2,972	1,088	1,495	0.366
86	100	158	13	141.0	25	4,869	1,098	4,385	0.225
32	100	212	0+	126.0	25	2,352	1,093	930	0.457
86	100	212	4	146.0	25	2,166	1,099	1,206	0.507
32	100	95	11	60.0	100	1,974	1,073	1,836	0.544
59	100	95	31	70.0	100	1,679	1,076	2,733	0.641
86	100	95	74	88.0	100	1,476	1,081	9,725	0.733
32	100	158	2	79.0	100	1,692	1,079	876	0.636
86	100	158	13	99.5	100	1,390	1,085	1,329	0.781
140	100	158	63	140.9	100	1,119	1,098	3,879	0.981
32	100	212	0+	90.0	100	1,582	1,082	625	0.684
86	100	212	4	106.0	100	1,350	1,087	721	0.804
176	100	212	47	176.5	100	1,130	1,108	2,002	0.972

In the above table:

t_1 = temperature F. of ingoing air.
h_1 = relative humidity of ingoing air.
t_2 = temperature of heated air.
h_2 = relative humidity of heated air.
t_3 = temperature of outgoing air.
h_3 = relative humidity of outgoing air.

It will be seen that the efficiency $\frac{H}{G}$ increases as the temperature of the entering air, t_1, and the relative humidity of the leaving air, h_3, increase.

Air Pressure.—*Static pressure* may be considered as the pressure necessary to overcome the frictional resistance offered to the flow of air. It is measured by means of a Pitot tube and is expressed in inches of water pressure.

Velocity Pressure.—Velocity pressure is that pressure required to create the velocity of air flow. *Total pressure* or *dynamic* or *impact pressure* is that pressure required to overcome frictional resistance and to create the velocity of flow, and is the sum of the static and velocity pressures.

Pitot Tube.—This instrument consists essentially of two parts: (1) a tube pointing upstream against the flow of air, converting the sum of the static pressure and velocity pressure into a head which may be measured; and (2) a means of determining static pressure alone. For the latter measurement the Pitot tube is fitted with two small openings 0.02 of an inch in diameter. These openings connect with a tube which in turn is attached to an inclined manometer filled with a light liquid such as gasoline, which gives a sharp meniscus. The total pressure orifice is also connected to a similar inclined manometer by flexible rubber tubing.

The pressures are reported in inches of water, due allowance being made for the specific gravity of the liquid used in the manometer and for the inclination of the manometer.

Calculation of Air Velocity.—The difference between the total and static pressures is the velocity pressure, from which the air velocity can be calculated by the following formula:

$$V = 4{,}101\sqrt{p}$$

where

p = velocity pressure in inches water gage determined by actual test.

V = velocity in feet per minute (calculated from p).

Effect of Revolutions per Minute of Fan.—The volume of air discharged by a fan varies directly as the number of revolutions and the pressures produced vary as the square of the revolutions. The power required to operate the fan varies as the cube of the revolutions. These facts explain the startling increase in horsepower required for the operation of fans when the revolutions per minute and volume of air delivered are increased by moderate amounts.

Effect of Static Pressure.—Static pressure is increased by decreasing the size of air ducts, by increasing their length, or by inserting sharp

bends. Static pressure also increases with the square of the air velocity, and therefore in comparing the static pressures of any two dehydraters the relative air velocities must be taken into account. The volume of air delivered by the fan decreases as static pressure increases. Thus, a fan which delivers 23,600 cubic feet of air at 350 revolutions per minute and 1-inch static pressure will deliver at 2 inches static pressure only 14,700 cubic feet.

Air ducts should be large so that static pressure is not excessive, and for the same reason the distance between trays should be great enough to permit unimpeded air flow. The velocity of air in return flues or passageways between the fan and the drying compartment should not exceed 1,000 feet per minute, so that static pressure is not excessive.

The results of measurement of static pressure in several typical air-blast dehydraters in California are given in Table 61.

TABLE 61.—COMPARATIVE STATIC PRESSURES IN VARIOUS DEHYDRATERS
(*After Cruess and Christie*)

Plant No.	Type of dehydrater	Static pressure in inches of water		
		At fan intake (suction)	At fan discharge (pressure)	Total static pressure
E	Air-blast tunnel with partial recirculation	......	....	0.52
E	Air-blast tunnel with total recirculation	......	....	0.56
N	Ceramic oven	−0.65	0.51	1.16
G	Air-blast tunnel, direct heat	−0.93	0.86	1.79
G	Air-blast tunnel, direct heat, no recirculation	−0.81	0.43	1.24
G	Air-blast tunnel, direct heat, complete recirculation	......	....	2.63
O	Air-suction tunnel, no recirculation	−1.63	0.07	1.70
O	Air-suction tunnel, partial recirculation	−1.76	0.13	1.89
O	Air-suction tunnel, total recirculation	......	....	2.19
P	Air-suction tunnel, tray and slide type	......	....	0.70
B	University Farm type:			
	No recirculation	−0.85	0.67	1.52
	Total recirculation	−0.16	0.74	0.90
P	No recirculation	......	....	1.28

It is difficult to set a standard for maximum static pressure for dehydraters, but for a horizontal air-blast tunnel dehydrater 50 feet in length

and approximately 50 square feet in cross-section, the static pressure should not exceed 2 inches at an air velocity of 500 feet per minute when the tunnel is filled with cars and trays of fruit.

Recirculation of the Air.—If the air used in drying fruit or vegetables is allowed to escape into the outside atmosphere after its passage through the dehydrater, a great deal of heat is lost. For example, if 10,000 cubic feet of air per minute is used and is heated from 60 to 160°F. and in going through the dehydrater drops to 120°F., it will still be at a temperature 60°F. above that of the outside air. If the air is returned to the heating chamber and is used again, this heat will be conserved; or conversely, if fresh air is drawn into the dehydrater to replace that discharged from it, approximately twice as much heat is required to heat the fresh air as that required to heat the spent air.

Certain fruits case-harden, that is, become over-dried on the surface, and drying thereby is retarded. This condition is, to a large extent, avoided if the relative humidity of the air is increased sufficiently, which can be done to a large degree by return of the spent air.

Because of these facts, it is customary in modern dehydraters to provide for recirculation of a portion or all of the air used in drying.

In the dehydraters ordinarily used in California, it is found desirable to close the air-escape damper completely and to operate the dehydraters with complete recirculation of the air in the drying of prunes, apricots, peaches and pears, and with recirculation of about 75 per cent of the air in the dehydration of grapes, apples, sliced vegetables and other rapidly drying materials. Leakage through cracks, around doors, etc., is sufficient to allow escape of enough air to carry from the dehydrater the moisture liberated from the fruit or vegetables.

In an experiment at the University Farm in 1920, it was found that recirculation of the air during the drying of grapes resulted in a saving in fuel of approximately 50 per cent.

Air Distribution.—Not only must the dehydrater be furnished with a sufficient volume of air, but the air so furnished must be applied to the product to be dried in an evenly distributed manner.

Frequently the space above the topmost tray on a dehydrater car is too great, and an excessively large proportion of the air flows through this space; or it may flow beneath the cars or beside them instead of between the trays.

By the placing of baffles on the walls of the dehydrater or on the cars, it is usually possible to force the air into the desired channels. Table 62 gives the results of air-flow measurements in a dehydrater before and after installation of air baffles.

TABLE 62.—EFFECT ON AIR DISTRIBUTION OF PROPER PLACING OF BAFFLES
(*After Cruess and Christie*)

Location of test	Velocity before installing baffles, feet per minute	Velocity after installing baffles, feet per minute
Velocity of air between trays near top of car	320	600
Velocity of air between trays near bottom of car	400	420
Velocity of air below cars	1,500	500
Velocity of air above top tray	2,800	500

Methods of Obtaining Air Flow.—Two means of obtaining air flow in dehydraters are in commercial use. These are by natural draft and by forced draft. In the former method the tendency for hot air to rise is used and in the second method some form of fan is employed to force the air through the dryer.

Natural-draft and forced-draft dehydraters will be discussed in greater detail later in this chapter.

Parallel and Counter Current Systems of Drying.—In most tunnel dehydraters the fresh fruit enters at the air-exhaust end and the dried fruit leaves at the air-intake end of the drying compartment. During drying, the fruit is moved from air of moderate temperature (100 to 120°F.) at the start of drying to temperatures of 150 to 190°F. near the end of the drying period. This is termed the "counter current" system. During the first stages very little drying occurs because of the moist condition and relatively low temperature of the air. The drying process is completed in air of high temperature and low relative humidity, conditions that favor case-hardening and scorching of the fruit.

In the so-called "parallel current system," the fruit enters at the air-intake end of the drying compartment and is taken from the dehydrater at the air-exhaust end; the drying process is started in hot, dry air and is completed in warm, moist air. For some fruits this system possesses the following advantages:

1. Evaporation of the surplus moisture is very rapid during the initial stages of the drying period when the fruit is moist and in the best condition to give up its water.

2. The wet fruit is more nearly at the temperature of the wet-bulb thermometer because the fruit contains sufficient moisture to maintain a rapid rate of evaporation which reduces its temperature proportionately. This permits higher drying temperatures than are now used, thus still further increasing the rate of drying. In the counter current system the fruit near the end of the drying process, because of its low moisture content and slow rate of drying, is very apt to approach the temperature of the hot, dry air and become scorched and caramelized. The parallel

current system takes fuller advantage of the great drying power of air direct from the heating chamber.

3. The fruit gradually progresses during drying toward a region of lower temperature and higher humidity, so that scorching and overdrying are minimized.

4. The fruit emerges after drying at a relatively low temperature, so that much less heat is carried to the outside atmosphere by heated cars, trays and fruit than is the case with the counter current system.

The counter current has proved more satisfactory than the parallel current system for the dehydration of prunes, while the parallel system is better adapted for the drying of small fruits and sliced or cubed products.

Methods of Heating Air.—The air used in dehydration in commercial plants is usually heated by contact with steam pipes or with large flues heated by the products of combustion of crude oil, wood, coal or other fuel. It may also be heated by means of electrically heated wires or grids, or by mixing with the products of combustion of a clean-burning fuel, such as stove distillate, kerosene or gas. All of these methods are used commercially.

The method in which the products of combustion are mixed with the air used in drying is the most efficient because radiation and stack losses are reduced to a minimum.

Area of Heating Surface.—Formulas exist for the calculation of the area of the heating surface required for the heating of a given volume of air. Expressed in the metric system, one formula is as follows (after Hausbrandt):

$$H = \frac{Cg}{tm\left(2 + \frac{10}{c}\right)}$$

where H = area of the heating surface in square meters.
tm = mean difference in temperature between heating surface and air.
c = velocity in meters per second.
Cg = calories per hour.

The coefficient of heat transmission, k, varies with the square of air velocity in accordance with the following formula:

$$k = 2 + 10\sqrt{c}$$

where c = velocity of the air in meters per second.

From the first formula given above, it is also evident that heat transfer varies directly with the difference in temperature of the heating surface and the air undergoing heating.

From these considerations it would appear advisable to maintain the heating surface at a relatively high temperature and to carry the air

through the heating chamber with fairly high velocity. If the air is conducted from the cooler to the warmer portions of the heating system, a larger proportion of the heat will be absorbed by the air than if it is conducted in the opposite direction.

Fuel Efficiency.—We may define fuel efficiency as that proportion of the total heating value of the fuel actually utilized in evaporating moisture from the fruit. For example, if an amount of fuel is burned sufficient to evaporate 1,000 pounds of water, and if only 500 pounds of water are evaporated, the fuel efficiency is $\frac{500}{1,000}$, or 50 per cent.

Since approximately 1,000 B.t.u. of heat are required to evaporate 1 pound of water, and since 1 gallon of fuel oil will furnish approximately 142,000 B.t.u., a simple formula for calculating the efficiency of a given dehydrater is the following:

$$\frac{\text{Pounds fresh fruit} - \text{pounds dry fruit}}{\text{Gallons of oil consumed} \times 142} = \text{fuel efficiency.}$$

Data were collected upon a number of dehydraters in California in 1920 and their efficiencies were calculated by means of the above formula, with the results shown in Table 63.

TABLE 63.—COMPARATIVE FUEL EFFICIENCIES OF SEVERAL TYPES OF DEHYDRATERS
(*After Cruess and Christie*[14])

Plant No.	Type of dehydrater	Fruit dried	Fuel efficiency, per cent
E	Air-blast tunnel indirect heat	Apricots	58
N	Ceramic oven	Apples	50
F	Air-blast tunnel direct heat	Grapes	48
N	Ceramic oven	Grapes	44
E	Air-blast tunnel indirect heat	Peaches	43
E	Air-blast tunnel indirect heat	Pears	43
B	Air-blast tunnel indirect heat	Prunes	42
J	Air-blast tunnel	Prunes	39
J	Air-blast tunnel (same design as preceding but in another location)	Prunes	38
E	Air-blast tunnel indirect heat	Grapes	38
H	Air-blast cabinet	Prunes	30
M	Stack-type gravity air flow	Prunes	24
M	Small stack-type gravity air flow	Apricots	14

A well-designed dehydrater should have a fuel efficiency, calculated by the above formula, of at least 40 per cent in drying prunes or grapes, but an efficiency above 50 per cent is very difficult to attain under usual conditions.

Effect of Temperature of Air on Drying Rate and Efficiency.—The capacity of air to take up moisture rapidly increases with rise of temperature and the amount of heat necessary to evaporate a given weight of water decreases with rise in temperature (see Table 45).

Critical Temperature.—The temperature of the air used in dehydration not only greatly affects the time required for drying, but also the quality of the finished product. In order to secure large capacity and minimum operating costs, it is necessary to use the highest temperature that will not materially injure the product. Most dehydraters which involve a progressive movement of the fruit through the drying chamber have used the counter current system. The "critical temperature" for any fruit is the temperature at which, when the fruit is almost dry, it may undergo undesirable changes in color or flavor. In the counter current system this temperature is the maximum which can be used, while in the parallel current system, this temperature must not be exceeded in the final stages of drying, although much higher temperatures can be used while the fruit still contains an excess of moisture.

The maximum advisable finishing temperatures for each of the more important fruits are given in Table 72.

Experiments by Gadgil, Winkler and Bjarnason, graduate students in the University of California, indicated rapid loss of sugar when raisins were heated to 185°F. after becoming nearly dry. At lower temperatures, the effects were negligible unless the raisins were allowed to become very much overdried, a condition which should never occur in a commercial plant. The extent of such sugar loss is indicated in Table 64.

TABLE 64.—LOSS OF SUGAR FROM RAISINS SUBJECTED TO VARIOUS TEMPERATURES

Temperature, °F.	Hours exposed	Per cent of sugar loss
140	8	0.6
140	16	0.8
140	32	1.0
167	8	1.3
167	16	1.9
167	32	6.2
185	8	8.7
185	16	12.2
185	32	14.9

Relative Humidity.—Relative humidity of air may be defined as its percentage of saturation with moisture vapor. Air completely saturated with water vapor at a given temperature is at 100 per cent relative

humidity; air at the same temperature containing one-half the amount of water vapor that it is capable of absorbing is at 50 per cent relative humidity. The absolute amount of water vapor that air can absorb (within certain temperature limits) approximately doubles with each 27° F. rise in temperature.

Case-hardening.—Large pieces of fruit, such as halved pears, peaches or whole Imperial prunes, case-harden if the relative humidity is so low and the temperature so high that the moisture is removed more

FIG. 80.—Wet and dry bulb thermometers of type commonly used for determination of relative humidity in dehydraters.

rapidly from the surface than it diffuses from the interior of the fruit. Case-hardening (searing over of the surface) retards the rate of evaporation because it impedes the diffusion of water to the surface of the fruit.

In drying pears and peaches it has been found that case-hardening was materially reduced by increasing the relative humidity of the air at 150°F. to 30 to 35 per cent.

Thinly sliced fruits (*e.g.*, pears, apricots and peaches), dipped grapes, small- to medium-size prunes and dipped cherries do not case-harden seriously (see Table 72, column 5).

Dew Point.—Relative humidity may also be defined as the ratio of the vapor pressure of the water vapor present in a given space to the vapor pressure of water vapor in that same space saturated with water vapor. The saturation point is ordinarily known as the dew point (*i.e.*, 100 per cent relative humidity).

Determination of Relative Humidity.—Relative humidity is determined by comparison of the temperatures of wet- and dry-bulb thermometers. Evaporation of moisture from the wet-bulb thermometer causes a drop in temperature in proportion to the rate of evaporation,

which is dependent upon the relative humidity of the air. Table 65 published by the Foxboro Instrument Company, gives the relation between wet-bulb, dry-bulb and relative humidity for temperatures commonly met with in the dehydration of fruits.

Table 65.—Relation of Humidity to Difference in Temperature of Wet- and Dry-bulb Thermometers

(*After The Foxboro Company, Inc., Foxboro, Mass., catalogue* 101–1, *p.* 9)

Dry bulb, deg. F.	Difference between readings of wet and dry bulbs in degrees F.																																				Dry bulb, deg. F.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	22	24	26	28	30	32	34	36	38	40	45	50	55	60	65	70	
70	95	90	86	81	77	72	68	64	59	55	51	48	44	40	36	33	29	25	22	19	12	6	0	0	..	..	..	..	..	..	..	..	..	..	..	..	70
75	96	91	86	82	78	74	70	66	62	58	54	51	47	44	40	37	34	30	27	24	18	12	7	1	0	..	..	..	..	..	..	..	..	..	..	..	75
80	96	91	87	83	79	75	72	68	64	61	57	54	50	47	44	41	38	35	32	29	23	18	12	7	3	0	..	..	..	..	..	..	..	..	..	..	80
85	96	92	88	84	80	76	73	70	66	63	59	56	53	50	47	44	41	38	35	32	27	22	17	13	8	4	0	0	..	..	..	..	..	..	..	..	85
90	96	92	89	85	81	78	74	71	68	65	61	58	55	52	49	47	44	41	39	36	31	26	22	17	13	9	5	1	0	..	..	..	..	..	..	..	90
95	96	93	89	85	82	79	75	72	69	66	63	60	57	54	52	49	46	43	42	38	34	30	25	21	17	13	9	6	2	0	..	..	..	..	..	..	95
100	96	93	89	86	83	80	77	73	70	68	65	62	59	56	54	51	49	46	44	41	37	33	28	24	21	17	13	10	7	4	0	..	..	..	..	..	100
105	97	93	90	87	83	80	77	74	72	69	66	63	60	58	55	53	50	48	46	44	40	36	32	28	23	20	16	13	11	8	0	..	..	..	..	..	105
110	97	93	90	87	84	81	78	75	73	70	67	65	62	60	57	55	52	50	48	46	42	38	34	30	26	23	20	17	14	11	4	0	..		..	..	110
115	97	94	91	88	85	82	79	76	74	71	68	66	63	61	58	57	54	52	50	48	43	40	36	32	28	26	22	20	16	14	7	2	0	..	..	..	115
120	97	94	91	88	85	82	80	77	74	72	69	67	65	62	60	58	55	53	51	49	45	41	38	34	31	28	25	22	19	17	10	5	0	..	..	..	120
125	97	94	91	88	85	83	80	78	75	73	70	68	66	63	61	59	57	54	52	50	47	43	40	36	33	30	27	24	22	19	13	7	2	0	..	..	125
130	97	94	91	89	86	83	81	78	76	73	71	69	67	64	62	60	58	56	54	52	48	45	41	38	35	32	29	26	24	21	15	10	6	1	0	..	130
135	97	94	92	89	86	84	81	79	76	74	72	69	67	65	63	61	59	57	55	53	50	46	43	40	36	34	30	28	26	23	18	12	8	3	0	..	135
140	97	95	92	89	87	84	82	79	77	75	73	70	68	66	64	62	60	58	56	54	51	47	44	41	38	35	32	30	27	25	19	14	10	5	2	..	140
145	98	95	93	90	87	84	82	80	78	75	73	71	69	67	65	63	61	59	57	55	52	48	45	42	39	36	34	31	29	27	21	16	12	7	4	0	145
150	98	95	93	90	87	85	82	80	78	76	73	71	70	68	65	64	62	60	58	56	53	49	46	43	41	38	35	33	30	28	23	18	13	9	5	2	150
155	98	95	93	90	87	85	83	81	79	76	74	72	70	68	66	64	63	61	59	57	54	50	47	44	42	39	37	34	32	30	24	19	15	11	7	4	155
160	98	95	93	90	88	85	83	81	79	77	75	73	71	69	67	65	63	62	60	58	55	51	48	46	43	40	38	35	33	31	25	21	16	12	9	6	160
165	98	95	93	91	88	86	84	82	80	78	75	73	72	70	68	66	64	62	61	59	56	52	49	47	44	41	39	37	34	32	27	22	18	14	10	7	165
170	98	96	94	91	89	86	84	82	80	78	76	74	72	70	69	67	65	63	62	60	57	53	50	48	45	42	40	38	35	33	28	23	19	15	12	9	170
175	98	96	94	91	89	86	84	82	81	79	76	74	73	71	69	67	66	64	62	61	58	54	51	49	46	43	41	39	36	34	29	25	20	17	13	10	175
180	98	96	94	92	89	87	85	83	81	79	77	75	73	72	70	68	66	64	63	61	58	55	52	50	47	44	42	40	37	35	30	26	21	18	14	12	180
185	98	96	94	92	89	87	85	83	81	80	77	76	74	72	70	69	67	65	64	62	59	56	53	50	48	45	43	41	38	36	31	27	22	19	16	13	185
190	98	96	94	92	90	87	85	83	82	80	78	76	74	73	71	69	68	66	64	63	60	57	54	51	49	46	44	42	39	37	32	28	24	20	17	14	190

In using the table, in the topmost horizontal row find the difference in temperature nearest that of the observed *difference* in temperature between the wet- and dry-bulb thermometers. Follow down the vertical column directly beneath this difference in temperature until this vertical column cuts the horizontal row opposite the dry-bulb thermometer temperature. The figure at the point of intersection is the relative humidity. An example will make this explanation clearer:

Dry-bulb reading, 130°F.; wet-bulb reading, 103°F.; difference, 27°F. In Table 65, 28° is the nearest temperature given. Follow down 28°F. column until the horizontal row opposite 130°F. is met. At this point of intersection will be found 38, the approximate per cent relative humid-

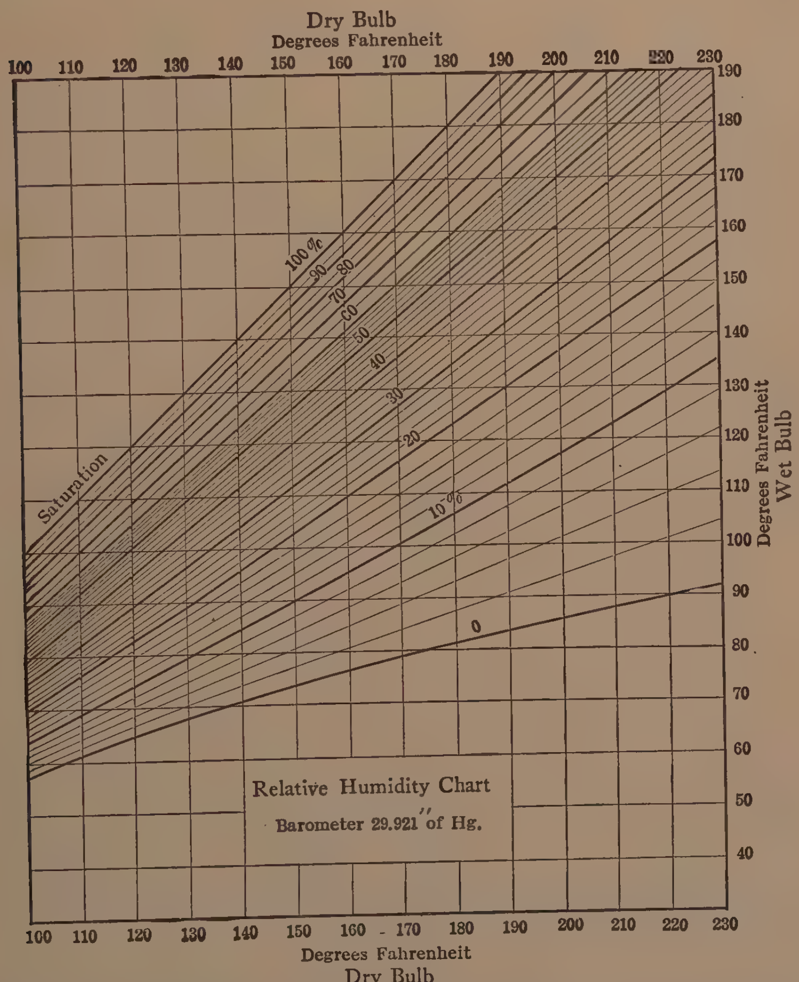

FIG. 81.—Relative humidity chart (prepared by G. B. Ridley, Heinemann Pearson Co., S. F.). (*After Bulletin* 337 *Univ. of Calif. Exp't. Sta. by Cruess and Christie*).

ity. More accurate results are obtainable by interpolation or by use of the chart shown in Fig. 81.

Humidity Chart.—In Fig. 81 is shown a relative humidity chart prepared by G. B. Ridley. The chart is self-explanatory and more convenient than tables.

Vapor Pressure.—The pressure causing water to evaporate is vapor pressure. The vapor pressure of partially saturated air may be calculated by various formulas from wet- and dry-bulb readings.[11]

Temperature of Product.—It is reasonable to suppose that as long as the evaporation is not forced beyond the ability of the material undergoing drying to part with its free water, its temperature will be essentially that of the wet-bulb thermometer and its vapor pressure will be that of the saturated vapor at that temperature. When the attempted rate of evaporation is greater than that at which the material can give up its moisture, the temperature of the material will rise above that of the wet-bulb thermometer and the condition will be like that of an autoclave from which the rate of flow is controlled by a cock.

Heat Losses.—The greatest heat loss in dehydration is that in the exhaust air. Under some conditions this may amount to 50 per cent of the total heat generated in the furnace, and is frequently more than 25 per cent of this total. By recirculation of the air this loss can be greatly reduced, but not entirely eliminated under practical working conditions.

Leakage of air through cracks or around door sills, etc., and radiation of heat from the walls may also become serious causes of heat losses.

Considerable heat is lost in the gases from the stack of the furnace or boiler. With a properly designed and operated furnace and radiating pipe type of heating apparatus the temperature of the flue gases at the outlet of the stack should not be above 200°F.

TYPES OF DEHYDRATERS

There are many forms of dehydraters in commercial use and many others which have been designed by various inventors and patented, but not used commercially. In many cases dehydraters have been designed and built, but have failed to perform satisfactorily because the fundamental principles of dehydration were not understood or considered.

A satisfactory dehydrater should permit of close control of temperature, air velocity and relative humidity.

Because of space limitation it is impossible to give in this book complete plans and specifications for even the more important types of dryers. A brief description only of the more important features of dehydrater types in commercial use will be given. A list of bulletins of state Experiment Stations and of the U. S. Department of Agriculture and other publications, some of which give working specifications for various evaporators and dehydraters, will be found at the end of this chapter.

In general, we may place dryers in three classes, namely: (1) natural-draft dryers; (2) forced-draft dryers; and (3) distillation dryers, including those operating under vacuum.

Natural-draft Dryers.—Most of the dryers used in New York State and California for the drying of apples and hops and in Oregon and Washington for the drying of fruits are of the natural-draft type, which requires no fan. They possess the advantages of simplicity of construction and operation and although inefficient in their use of fuel, are relatively inexpensive to build.

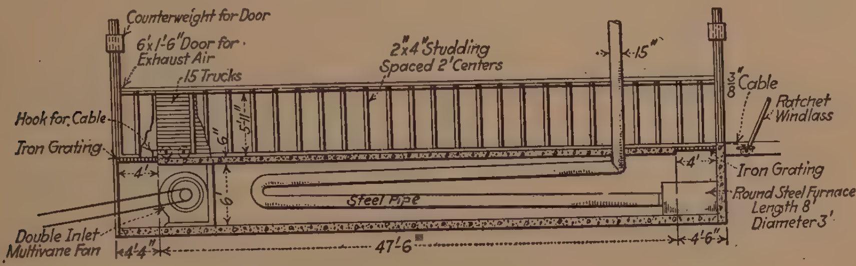

FIG. 82.—Recirculating air blast dehydrater. (*After Wiegand*).

Natural-draft dryers, in general, consist of a furnace room or steam pipes surmounted by a drying chamber. Cold air enters the furnace room near the ground level, is heated by contact with the furnace radiating pipes or steam coils and rises through the drying compartment, where it comes in contact with the fruit or other product undergoing drying.

Kiln Dryer.—The kiln dryer, one of the oldest types still in commercial use for the drying of apples and hops, is constructed in two stories. The upper story houses the drying floor, which is usually about 20 feet square and made up of strips of hard wood ¼ inch apart. Over the floor is a steep four-sided roof, equipped at the apex with a large ventilator for the escape of spent air. The prepared fruit or other product is placed directly on the floor in a layer 3 to 12 inches in depth, and is stirred with a fork or scoop shovel during drying.

The furnace room houses a large wood-, coal- or oil-burning furnace connected to a series of large sheet metal pipes which are led around the furnace room several times before joining the stack. In some cases the furnace and radiating pipes are replaced with a steam boiler and steam pipes, the latter placed immediately beneath the drying floor. While more expensive to install, the steam heated kiln permits of more careful regulation of the temperature and makes possible the use of higher temperatures than is feasible with the usual pipe and furnace type of kiln.

The kiln dryer is satisfactory for hops and gives fairly satisfactory results in the drying of apples, but is unsuited to the drying of soft fruits, such as prunes, grapes, peaches, etc., because of bruising. (For details of construction see reference 21 at end of this chapter.)

The Tower Dryer.—The "tower" or "stack" dryer consists of a furnace room about 10 feet in height, in which are located a furnace and

heating pipes of the same general design as the heating system used for the Oregon tunnel dryer and of cabinets in which trays of fruit are dried. Each stack or cabinet holds about 12 trays, usually 3 feet square in size and each furnace room usually accommodates six stacks of trays. The heated air from the furnace rises through the trays.

In operating this dryer the cabinets are filled with trays of the fresh fruit and as the trays at the bottoms of the stacks become dry they are removed and are replaced with freshly loaded trays, which are entered on the topmost tray runways. Each time a fresh tray enters the stack the whole set of trays is shifted downward one tray.

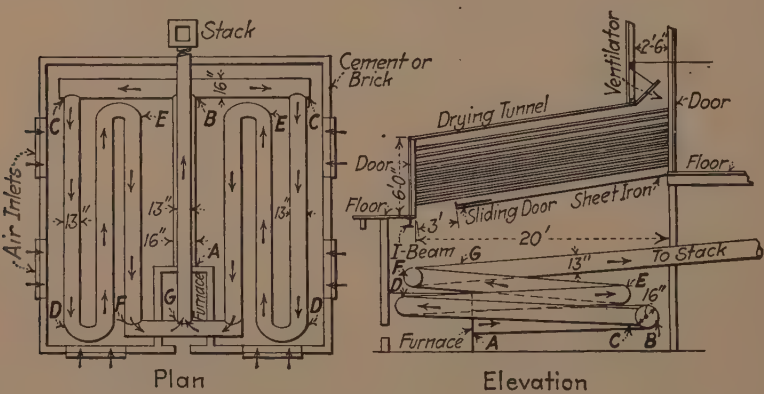

FIG. 83.—Sketch of Oregon tunnel dryer showing arrangement of heating pipes. (*After Lewis*).

The Cabinet Dryer.—This dryer is similar in design and in operation to the stack dryer, but heat for drying is furnished by steam coils placed between the trays. Drying is rapid and the temperature can be very conveniently and exactly regulated. It is a very great improvement over the old stack dryer. (For details of construction see reference 5 at the end of this chapter.)

The Oregon Tunnel Dryer.—This is the most popular dryer in use in the Pacific Northwest. It was invented by Allen about 25 years ago and is often known by his name.

In a general way, it may be described as a series of parallel, sloping narrow chambers above a furnace room. The trays of fruit enter the dryer at the upper or cooler end on runways and progress toward the lower or warmer end. The dry fruit is removed from the lower end of each tunnel. The surface room is similar in design to that used for the kiln dryer and the drying tunnels rest on a floor about 12 to 16 feet above the floor of the furnace room, which serves two to four tunnels. Each tunnel is about 20 feet long by about 5 feet in height and about 3 feet in width and slopes approximately 2 inches per foot. At one time tunnels

were much longer than 20 feet, but more rapid and uniform drying is obtained by the shorter tunnels. Hot air enters the lower end of each tunnel through an opening or "throat" approximately 3 feet in width, which is fitted with a sliding door by means of which the amount of air passing through the dryer can be regulated. Figure 83 illustrates the main features of an Oregon tunnel dryer.

At present many owners of tunnel dryers are installing fans by means of which most of the air is recirculated and the efficiency of the tunnels greatly increased.

There is a considerable difference in the temperature of air at the upper and lower ends of the tunnel, a fact which renders the tunnel dryer more efficient in its use of fuel and heat than tower or kiln dryers, but nevertheless the Oregon tunnel is less efficient than air-blast dryers. The temperature at the upper end of the tunnel is usually 30 to 50°F. lower than at the furnace end and on this account the tunnel dryer is especially well adapted to the drying of prunes, since overheating, bursting and dripping of the fresh fruit is avoided.

Ceramic Oven.—Dryers built on a design similar to that of a bake oven have been built in California. The walls are of heavy masonry and firebrick and heat is radiated from the walls, ceiling and floor to the fruit, which is held on trays on trucks. Owing to uneven and slow drying of the fruit occasioned by inadequate air flow, this dryer has in recent years been equipped with forced draft and a recirculation system with marked improvement in the rate of drying.

Distillation Type at Atmospheric Pressure.—In this type of dryer the moisture is driven from the product by heat and the water vapor so evolved is condensed by water-cooled coils or by sprays of cold water. This principle has not been applied commercially to the drying of fruits, although it is used in lumber kilns.

Vacuum Dehydraters.—Vacuum dehydraters are in use for the drying of some chemicals and other manufactured products which are easily injured by high temperatures and oxidation. Drying in vacuo permits the use of low temperatures of drying and minimizes oxidation, but the equipment needed is rather complicated and expensive and, for these reasons, has not found general application in the drying of fruits and vegetables.

In its commercial form, the vacuum dehydrater consists of a heavy-walled sheet-metal or cast-iron chamber fitted with steam-heated shelves or coils on which rest trays of the material to be dried. The chamber is connected with a vacuum pump and spray or coil condenser for maintaining a high vacuum and for condensing moisture liberated in the drying compartment.

Dehydration in a vacuum requires less heat than in a dryer operating with heated air, because most of the heat supplied to the vacuum dryer is used in the evaporation of moisture.

Because it reduces the tendency for fruits to darken it is possible that the vacuum method of dehydration may be employed as a means of reducing the length of sulphuring of fruit before dehydration, or in some cases of completely eliminating sulphuring.

Forced-draft Tunnel Dehydrater.—The forced-draft tunnel dehydrater has proved to be the most efficient type of dryer in commercial use in California for the drying of fruits. It also permits of most rapid drying without injury, is the cheapest dehydrater to build and to operate and permits of more uniform drying. It normally consists of a chamber longer than wide, through which the product to be dried moves progressively on trays. The drying chamber or tunnel is supplied with a current of heated air which is introduced at one end and removed from the opposite end.

Methods of Heating the Air.—The air used in forced-draft dryers is heated in one of three ways: by steam coils, hot-air furnaces or by mixing with the products of combustion from the furnace. Steam is the most expensive method to install and operate, but permits of exact regulation.

Hot-air furnaces and heating systems have been described for the kiln dryer. Similar systems are in use for heating air in forced-draft dryers of all types.

Direct heating of the air by mixing it with the products of combustion has been used successfully in several dehydraters. Fuel is burned in a furnace in which is built a checkerwork of firebrick, which breaks up the flame and favors complete combustion. The products of combustion are mixed with cold outside air, or that returned from the drying chamber, and the mixed gases are drawn through the fan and forced into the tunnel. The thermal efficiency of this system is greater than either the steam heating or hot-air furnace systems. Figure 84 illustrates the direct and indirect air heating systems.

It requires a special grade of fuel, namely stove distillate, engine distillate or kerosene. In the drying of white fruits there is danger of blackening the fruit from the formation of soot in the furnace through incomplete combustion, because of clogging of the burners or temporary stopping of the motor operating the air line for the burners.

Fans.—The heated air is either forced through the tunnel under positive pressure by means of a blower fan or is drawn through the tunnel by means of a suction fan. Both are satisfactory. Where a suction fan is used the tunnel should be equipped with air locks at each end so that the cars of trays may enter and be removed from the tunnel without excessive reduction in temperature.

Fans are of three types: disc, multivane and paddle wheel. Under most conditions the multivane type of fan is to be preferred to the disc fan. The disc fan resembles a wind mill in appearance and is cheap but will not deliver air against appreciable static pressure. Figures 88 and 89

FIG. 84.—Upper: Air intakes and furnace doors of Oregon tunnel dryer. Lower right: Indirect air heating system. Lower left: Direct air-heating furnace.

FIG. 85.—Some types of dehydrater cars.

illustrate the two types. The paddle wheel fan is similar in principle to the multivane, but has fewer vanes. It is thoroughly satisfactory.

Relative Position of Furnace and Tunnel.—The furnace room may be located at one end of the tunnel, at the side or above or below the tunnel. It is advisable that it be so placed that the cars or trays may enter

Fig. 86.—Common types of dehydrater trays.

Fig. 87.—Types of dehydraters in California. Upper: Modern four tunnel air blast dehydrater. Lower: Obsolete natural draft stack evaporater.

one end of the tunnel and be removed from the opposite end without the necessity of transferring to separate cars. A very convenient arrangement is that in which the furnace and heating systems are located in a tunnel beside the drying tunnel, with the fan located in the furnace room. Air is delivered to the drying tunnel by a duct beneath the floor or in the

wall of the drying tunnel. No air locks or transfer systems are required under these conditions.

Cars.—The material to be dried is usually spread on trays which are either carried through the tunnel on cars or on runways, as in the Oregon tunnel dryer. The car system is the one more generally used. The cars operate on tracks in most cases, but may be equipped with

FIG. 88.—Disc fans. At left: Commercially built fan. At right: Home-made fan.

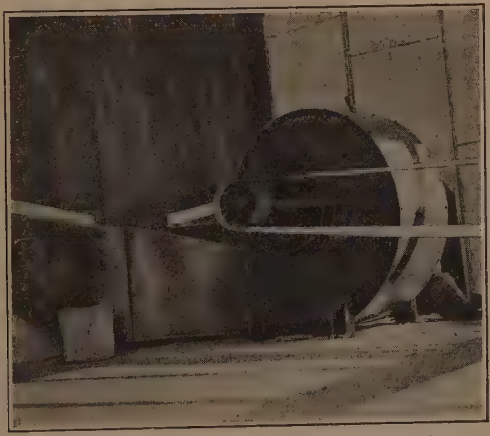

FIG. 89.—Multivane fan attached to dehydrater.

caster wheels to permit moving to any part of a concrete floor in the preparation room or dryer or may be carried by an overhead conveyor. In small tunnels the cars are moved by hand; in large plants they are drawn by a winch or by other power (see Fig. 85).

Recirculation.—It is desirable that the forced-draft tunnel dehydrater be so constructed that any proportion of the air may be recirculated. The return-air duct must be large enough to permit unimpeded

flow of the air, in order that static pressure shall not be excessive. The position of the return flue is optional, as it may be above, below or at one side of the tunnel. The furnace room may be so placed that it serves as a return flue.

Other Types of Forced-draft Dehydraters.—The stack dryer and Oregon tunnel dryers have, in some instances, been equipped with a fan to improve air circulation. The results obtained have more than compensated for the cost of such installations.

Continuous draper or belt tunnel dryers are in use for the drying of vegetables, starch, soap chips, etc. The dryer consists of a tunnel with several woven metal cloth endless conveyors placed one above the other. Air heated by steam coils is in one type blown lengthwise of the tunnel by a single large fan and in another type is blown across the trays at right angles to the greater diameter of the tunnel by several fans placed at the side of the drying compartment. One serious objection to the draper drier is that the drying area is much less than in a dehydrater of equal volume using trays.

Air-blast cabinet dryers are in use in which the trays are placed on runways in cabinets. Air is delivered between each pair of trays by a small duct or "tuyere" and the direction of flow is reversed frequently to insure uniform drying at all points on the trays. This dryer is unnecessarily complicated.

In other cases the air is forced upward through the trays, but resistance to air flow is so great that drying is slow and uneven.

Trays.—Dehydrater trays vary greatly in size, design and in materials of construction. Three types are shown in Fig. 86.

Screen Trays.—The most common tray used in the tower and Oregon tunnel dryers is made of a wooden frame and galvanized iron wire screen. The size of the trays is usually 3 by 3 feet or 3 by 4 feet. These trays are satisfactory for unsulphured fruits, but the zinc coating rapidly corrodes in sulphur fumes, the fruit absorbs zinc salts and acquires a metallic taste. With continued use the zinc is completely removed and the iron is exposed. This dissolves in fruit juices and reacts with the tannin of fruits to give iron tannate, causing the fruit to blacken where it comes in contact with the screen. No satisfactory coating has been found for such trays.

Slat Trays.—The most satisfactory tray for general use is the slat bottom tray, about 3 by 3 feet in size. It may consist of narrow wooden strips attached to a wooden frame with sides of 1½- by 3-inch material and ends of 1- by 2-inch pieces, when used on trucks in forced draft dehydraters. The height of the sides may be greater or less than that given above and the size of the trays larger or smaller, as desired.

Solid wooden bottom sun drying trays are sometimes used in dryers, particularly following early fall rains, in salvaging rain-damaged fruit.

When such trays are used, wooden strips must be placed between the ends to provide space for passage of the air. Drying is slower than on screen trays.

Trays 6 by 3 or 8 by 3 feet in size are not satisfactory where the air flows across the greater length of the tray, because the fruit on the end of the tray nearest the source of heat dries more rapidly than fruit at the opposite end; or if the direction of air flow is reversed frequently, the fruit near the middle of the tray dries more slowly than at the two ends.

Tray Capacity.—At the University of California dehydrater at Davis, trays held 2 pounds of medium-size halved apricots per square foot, 3 pounds of medium-size halved Muir peaches, 3 pounds of halved pears, 2½ to 3½ pounds of prunes one layer deep and 3 to 4 pounds of grapes. Sliced or cubed apples and cubed vegetables are loaded on trays at the rate of about 2 pounds per square foot.

Plant Investment.—For the average fruit grower the plant investment should be as low as is compatible with reasonable efficiency, because the duration of the fruit season is so short that it causes the overhead cost of plant investment to be excessive, unless the construction cost is low.

Cost per Ton Capacity.—A survey of dehydraters in California in 1920 and 1921 showed that it is possible to erect an efficient and satisfactory dehydrater for approximately $500 per green ton of fruit dried per 24 hours. The cost of buildings and accessory equipment is additional. The relation of plant investment to drying costs for several typical dryers in California is shown in Table 66.

TABLE 66.—COST OF DEHYDRATION AS AFFECTED BY PLANT INVESTMENT
(*After Cruess and Christie*)

Plant No. †	Type of plant	Capacity, green tons per 24 hours	Total first cost of plant	Cost of plant per green tons, 24 hours	Fixed charges per green ton on basis of 60-day season*					Total per dry ton
					Interest	Depreciation	Insurance	Taxes	Total	
A	Air-blast tunnel, direct heat..........	25.0	$12,000	$ 480	$0.56	$0.80	$0.10	$0.24	$1.70	$ 5.10
E	Air-blast tunnel Indirect Heat........	6.0	4,000	667	0.78	1.11	0.14	0.29	2.32	6.96
F	Air-blast tunnel, direct heat..........	35.0	25,000	715	0.83	1.19	0.15	0.32	2.49	7.47
H	Air-blast cabinet....	12.0	15,000	1,250	1.46	2.09	0.26	0.55	4.36	13.08
K	Small stack-type....	0.75	1,500	2,000	2.33	3.55	0.42	0.89	7.19	21.57
L	Air-blast stack-type.	1.50	4,000	2,666	3.11	4.44	0.55	1.48	9.28	27.84
M	Stack-type, large size	9.0	25,000	2,778	3.24	4.63	0.58	1.23	9.68	28.04
N	Ceramic oven.......	6.0	25,000	4,167	4.17	6.94	0.87	1.39	13.37	40.01

* Interest at 7 per cent; depreciation at 10 per cent; insurance at 2½ per cent of ½ value; taxes at 4 per cent of ⅗ value.

† These letters are used to designate the same dehydraters in other tables.

In the table, for comparative purposes, a drying season of 60 days was assumed; 30 days for drying grapes and the same length of time for prunes. A drying ratio of 3.5:1 was assumed for grapes and 2.5:1 for prunes, or an average ratio of 3:1.

Cost of Operation.—The cost of dehydrating prunes and grapes in several California dehydraters in 1920 is shown in Table 67. For comparative purposes uniform costs of 6 cents per gallon for fuel, 2½ cents per kilowatt hour for power and 50 cents per hour for labor were used.

TABLE 67.—COMPARATIVE COSTS OF DEHYDRATION

(*After Cruess and Christie*)

Plant No.	Type	Fruit	Cost per green ton					
			Labor	Fuel	Power and light	Total operating charges	Fixed charges, from Table 66	Total cost of production
D	Air-blast tunnel, direct heat	Prunes	$3.19	$0.94	$0.48	$4.61	$2.07	$6.68
E	Air-blast tunnel indirect heat	Grapes	4.16	2.05	0.45	6.66	2.32	8.98
H	Air-blast cabinet	Prunes	4.80	1.63	0.55	6.98	4.36	11.34
N	Ceramic oven	Grapes	4.56	1.44	0.59	6.59	13.37	19.96
M	Stack-type gravity air flow	Prunes	9.75	3.26	0.20	13.21	9.68	22.89

Natural-draft dryers showed a higher operating cost than forced-draft dryers (compare dryers *D* and *M* in Table 67).

Moisture Content of Dried Fruits.—The U. S. Department of Agriculture has placed the legal limit for moisture in dried apples at 24 per cent. It is likely that similar standards will in time be adopted for all dried fruits. In order to have a careful check on the moisture content, it is highly desirable for every plant to make frequent moisture determinations on representative samples. (See Cruess and Christie's "Laboratory Manual of Fruit and Vegetable Products" for methods of analysis.)

Experiments have proved that most fruits containing not more than 23 per cent of moisture will keep indefinitely. Unsulphured fruits containing 24 to 30 per cent of moisture sooner or later become moldy, while those above 30 per cent soon ferment unless heavily sulphured to prevent spoiling. These limits do not hold for sulphured fruits because of the preservative action of the SO_2.

Prunes containing more than 26 per cent of moisture in most instances become moldy.

Fireproof Construction.—The fire risk with most dehydraters built of wood is very hazardous and insurance rates on such structures very high.

On this account most of the dehydraters built in California in recent years have been constructed of hollow tile, concrete or other fireproof material. Insurance may then be dispensed with, except for trays and cars.

The greater original cost of fireproof dryers is compensated for within a few years by the saving in insurance cost and lower depreciation.

DEHYDRATION OF FRUITS

Dehydration affords a means of producing dried fruits of new forms and, in some instances, of better quality than is possible by sun drying. Practically all fruits can be successfully dehydrated, although some of these fruits do not yield acceptable products by sun drying.

Preparation.—Preparation of fruits for dehydration is similar to that for sun drying. A brief outline of approved methods of preparing some of the more important fruits is given below. The loss in preparing various fruits for dehydration is given in Table 68 (see also Tables 69 and 72).

Table 68.—Shrinkage in the Preparation and Dehydration of Various Fruits

(After Cruess and Christie)

Fruit	Per cent of fresh fruit unsorted					Drying ratio	
	Sorted uncut fruit	Prepared fruit cut, pitted, dipped or hulled	Prepared and peeled fruit	Loss in preparation	Dried fruit	Gross fresh to net dry	Prepared fresh to net dry
Royal apricots	100.0	92.3	.....	7.7	17.2	5.8:1	5.4:1
Muir peaches, unpeeled	96.4	90.3	.....	9.7	20.9	4.8:1	4.3:1
Muir peaches, lye peeled	96.4	90.3	86.2	13.8	19.9	5.0:1	4.3:1
Bartlett pears	97.9	91.7	.....	8.3	19.5	5.1:1	4.7:1
Bartlett pears, peeled	97.9	91.7	60.5	39.5	12.9	7.8:1	4.7:1
Grapes	100.0	100.0	100.0	....	27.5	3.6:1	
Newton apples	100.0	.....	75.0	25.0	12.3	8.3:1	6.1:1
Loganberries	100.0	100.0	100.0	....	21.1	4.7:1	4.7:1
Cherries, not pitted	100.0	100.0	100.0	....	33.5	3.0:1	3.0:1
Cherries pitted and stemmed	100.0	80.0	.....	20.0	23.7	4.2:1	3.4:1
Raspberries	100.0	100.0	100.0	....	14.8	6.8:1	6.8:1
Strawberries, four varieties	100.0	96.4	.....	3.6	16.7	5.9:1	

Comparative Yields and Qualities of Sun-dried and Dehydrated Fruits.—Accurately controlled comparisons of sun drying and dehydration of apricots, peaches, pears and prunes were made at the University of California in 1919 and 1920. Fruit of the same condition was used for the two methods of drying and any subsequent differences in the dried product were a direct result of the method of drying.

After drying, the fruit was again carefully weighed and representative samples withdrawn which were later analyzed for moisture and sugar. The figures obtained are given in Table 69.

TABLE 69.—COMPARATIVE YIELDS BY SUN DRYING AND DEHYDRATION OF VARIOUS FRUITS

Fruits and method of drying	Drying ratio	Moisture in dry fruit, per cent	Pounds dry fruit per 100 pounds fresh		Per cent of sugar in dry fruit	
			As weighed from tray	On 25 per cent water basis	As weighed from tray	On 25 per cent water basis
Apricots:						
In sun	5.1:1	15.6	19.7	22.1	50.1	47.5
In Univ. dehydrater	4.6:1	25.8	21.6	21.4	43.8	47.2
Peaches:						
In sun	4.8:1	17.8	20.9	22.9	49.1	44.8
In Univ. dehydrater	4.5:1	23.7	22.1	22.5	47.9	47.0
Prunes:						
In sun	1.5:1	15.0	66.2	74.8		
In Univ. dehydrater	1.5:1	14.4	67.1	76.3		

Consistently higher yields of dried prunes were obtained by dehydration, but for other fruits no appreciable difference in yield was noted by the two methods. The dehydrated fruits were superior in flavor and cooking quality to the sun-dried fruits, although not so attractive in appearance in some instances.

Apples. (see also Table 72).—There is an increasing demand for dehydrated apples of the highest quality, although the tendency in the past has been to produce quantity rather than quality, with the result that much of the usual commercial pack is only suitable for cheap export markets. The cleanest, whitest fruit that is well trimmed and carefully dried and packed is most in demand. In seasons of abundant crops and low prices for fresh fruit, large quantities of apples that would normally be sold fresh are dried and the grade of the dried product is correspondingly improved. In years of light crops, when all apples suitable for packing are in demand at high prices, only the poorer fruit is dried with, generally, a lowering of the quality of the dried fruit.

Varieties.—Dried apples are graded on texture and appearance rather than on flavor. Varieties that are firm and yield a dried product of white color are therefore preferred. In California, of the commercially grown varieties the Yellow Newton Pippin is the best for drying. In Oregon and Washington the Esopus (Spitzenberg) is in demand for

drying purposes. The Baldwin, Hubbardston and varieties of the Russet group are also satisfactory. The Gravenstein is one of the best of the early varieties for drying purposes. The Bellflower and some other important varieties yield dried products of yellowish color and are not greatly in demand for drying.

Sorting.—The apples should be carefully sorted to remove rot, wormy fruit, etc. and if possible, thoroughly washed before peeling. Sorting can be done on a broad belt.

Peeling and Coring.—Apples are peeled and cored in one operation by a machine, operated either by hand or by power. The peeling is done by a guarded blade similar to a safety razor. The peeling machine is also often equipped with a knife which cuts the peeled and cored apples into a spiral, which gives rings when cut crosswise. In many drying plants in order to facilitate trimming of the peeled fruit, it is merely peeled and cored in the peeling machine and is sliced in a separate machine.

Trimming.—Trimming is of great importance because some of the peeled fruit carries pieces of peel, bruises or portions of the calyx, which must be removed if a dried product of high quality is desired. There should be at least two workmen trimming for each workman engaged in peeling. Trimming can be done efficiently by girls or women stationed beside a slow-moving belt, or at sinks supplied with fruit by a belt which passes beneath the peeling machines.

Sulphuring.—Apples are always exposed to the fumes of burning sulphur before drying to bleach the surface of fruit, which has become brown by exposure, and to prevent further browning. The whole peeled fruit may be sulphured before slicing, in which case 45 to 90 minutes' exposure is required; or it may be sulphured after slicing, when 20 to 30 minutes' sulphuring will be sufficient. The fruit is either sulphured on the trays in the same manner as other fruit, or may be sulphured on a wooden slat conveyor in a long chamber.

If the sliced apples are dipped in a 3 to 5 per cent salt solution the period of sulphuring may be reduced to 15 minutes.

Cubing.—Apples are usually cut in slices (rings) about ¼ inch thick, but the demand is increasing for cubed dehydrated apples. Cubes about ½ inch in size are cut from the whole, peeled, trimmed and cored fruit by a special machine. These dry quickly and are convenient for use in pies.

A large fruit dehydrating company of Oregon now slices the apples before drying in very thin pieces by means of a sauerkraut cutter.

Dryers Used.—On the Pacific Coast, apples are generally dried on trays in a tower, Oregon tunnel dryers or air-blast dehydraters, while in New York and other apple growing sections of the eastern United States, the kiln dryer is more popular than those in which trays are used.

Temperatures.—In stack dryers in California a temperature of approximately 180°F. is used for drying the lowermost trays in each stack or tower. In air-blast dehydraters a lower temperature, 140 to 175°F., is employed. The lower temperature is less liable to cause browning of the color and caramelization of the sugar.

Drying Time.—The drying time for sliced apples in the stack dryer is about 10 to 12 hours; cubed or thinly sliced apples dry more rapidly. Apples lend themselves well to use of the parallel current system by which it is possible to dry them in 2 to 3 hours.

Yields.—In California approximately 7 tons of fresh, unsorted, unpeeled fruit is required to give 1 ton of dried product. In the Pacific Northwest, on account of the lower sugar content of the apples, about 10 tons of fresh fruit is required to yield 1 dry ton. Yields also vary greatly with different varieties.

Moisture Content.—Government regulations require that dried apples contain not more than 24 per cent of moisture when offered for sale.

Storing Dried Product.—The dried fruit is usually stored in large bins or in heaps on the store room floor, which is generally located in the basement of the building in which the dryer is housed. Care should be taken to exclude insects. The packing of dried apples is discussed in Chapter XXII.

Dehydration of Apricots.—Apricots are prepared as for sun drying, although 1 hour of sulphuring is usually sufficient as contrasted with 3 to 5 hours for fruit which is to be dried in the sun.

A temperature less than 160°F. should be used for apricots near the end of the drying period; best results are obtained at temperatures below 150°F.

Bananas.—This fruit is dried to a limited extent in the tropics in dryers of various types. Green fruit is peeled after loosening the skin by blanching. The peeled fruit is sulphured a short time, dried on trays until brittle, ground and bolted to make banana flour. Ripe bananas are peeled and dried whole. These are known in commerce as "banana figs." They are of dark color and unattractive appearance, but of fairly pleasing flavor. If the ripe fruit is sliced lengthwise and sulphured for 20 minutes before drying, a much more attractive product is obtained.

Large quantities of bananas go to waste in the tropics in the groves and at export ports because of slight blemishes, over-ripeness, etc. Dehydration is a means of conserving much of this fruit and rendering it available as food.

Cherries.—Cherries should be dipped in dilute boiling lye solution (¼ to ½ per cent NaOH) and rinsed in water.

White or pink cherries should be sulphured about 15 minutes. Black cherries require no sulphuring. See Table 72 for additional information.

Cherries may be pitted before dehydration and then require no lye dipping before drying. Dehydrated pitted cherries are excellent for pies, etc.

Figs.—Whole white figs which have been allowed to ripen, partially dry on the trees and drop to the ground before gathering can be dehydrated whole in 9 to 12 hours at 165°F. If cut in half, drying is much more rapid.

Grapes.—Grapes should be lye dipped before dehydrating. Muscat and wine grapes possess tough skins and require a relatively strong solution (2 to 3 per cent NaOH), while Sultanina (Thompson Seedless) and Tokay are tender-skinned and a dilute lye solution (¼ to ½ per cent NaOH) checks the skins satisfactorily. Sulphuring is not necessary, although the color of all varieties is improved by 30 to 60 minutes' exposure to sulphur fumes.

Grapes respond well to the parallel current system of drying, with an initial temperature of 200°F. and a finishing temperature of 160°F. In general practice, however, the counter current system is employed with an initial temperature of 110 to 120°F. and a finishing temperature of 160 to 165°F. Dipped grapes may be dried in 20 to 30 hours by the counter current system with a finishing temperature of 165°F.

Dehydrated white grapes, such as Muscat and Thompson Seedless varieties, are inclined to be more sticky on the surface than the sun-dried raisins and are usually lighter in color.

Loganberries.—This fruit is dried commercially in the Pacific Northwest both in large forced-draft commercial plants and in farmers' dryers of the Oregon tunnel type. No preliminary treatment, other than sorting, is necessary. Berries for drying should be firm ripe, for soft ripe fruit is apt to melt and form "slabs" and to lose a great deal of juice. For the same reason the berries should not be washed (see Table 72).

The parallel current is used very successfully both in Oregon tunnel natural-draft dryers and in forced-draft dehydraters. In the latter method an initial temperature of 180°F. and a finishing temperature of 145 to 150°F. can be used. A large company operating plants at The Dalles and at Salem, Ore. dries large quantities of loganberries very successfully at temperatures below 145°F. in an air-blast dehydrater.

Peaches.—Peaches should be halved, pitted and lye peeled as for canning. The halves are spread on the trays, cups upward. Slat trays, heavily coated with slab oil (neutral mineral oil), should be used in order to prevent sticking to the trays. The peaches should be sulphured about 3 hours, if a light-colored product is desired. There is also a small demand for unsulphured dehydrated peaches. Darkening of unsulphured peaches can be greatly reduced by blanching in steam on the trays until the halves are heated through to 185 to 212°F., normally about 5 minutes in live steam.

Peaches tend to case-harden seriously and on this account the relative humidity should be increased to about 30 per cent during the final stages of drying, and because of their tendency to caramelize peaches should not be dried at temperatures above 145°F. The drying under these conditions is about 30 hours.

Clingstone canning varieties yield an excellent dehydrated product and dehydrated freestone peaches, such as the Muir, Lovell, Elberta and Crawford, are equal in appearance to the sun-dried and superior in flavor and cooking quality.

Sliced peeled peaches yield a particularly attractive dehydrated product.

Pears.—Bartlett pears should be peeled and cored as for canning because the unpeeled halves prepared as for sun drying are not as attractive dehydrated as sun-dried.

The peeled halves are sulphured as described above for peaches and drying times, temperature and desirable relative humidity are about the same as for peaches. Pears may also be cubed or sliced, if desired.

Dehydrated pears are markedly superior to the sun-dried pears for culinary purposes, and after 24 hours' refreshing in water the fruit resembles the canned product in appearance and flavor (see Tables 68 and 72).

Dehydration of Prunes in California.—Prunes are prepared for dehydration in the same manner as for sun drying, although lye dipping should not be so severe because "heavy" dipping causes the dehydrated prunes to be sticky. Screen trays may be used, but slat trays are more durable and can be used for other fruits also. The dipped fruit is spread on the trays one layer deep.

Drying.—Prunes "drip" badly if the parallel current system is used; better results are obtained with the counter current, using an initial temperature of 110 to 130°F. and a finishing temperature of 160 to 165°F.

The relative humidity near the end of the drying period should be at least 20 per cent because of danger of case-hardening. This can be attained usually by recirculation of the air. The drying time is 24 to 36 hours in the dryers now in use on the Pacific Coast.

Cost of Dehydration.—Although most of the prune crop in California is dried in the sun, interest in dehydration is increasing and many new dehydraters are being built. At present, approximately 15 to 20 per cent of the crop is dehydrated. Christie[19] has recently (1922 season) made a survey of sun drying yards and dehydraters and compiled the comparative costs of sun drying and dehydration as given in Table 70.

Labor costs are less in dehydration than in sun drying and the saving in cost of this item partially compensates for the extra cost of fuel and power in dehydration.

TABLE 70.—COMPARATIVE COSTS OF SUN DRYING AND DEHYDRATION OF PRUNES IN CALIFORNIA, 1922, ON BASIS OF GREEN TON OF FRUIT

(*After Christie*)

Item	Dehydrater A	Dehydrater B	Dehydrater C	Dehydrater D	Dehydrater E	Average for dehydration	Average for sun drying
Labor	$1.90	$2.45	$2.78	$2.81	$3.42	$2.67	$3.68
Fuel	0.48	0.62	1.02	0.89	1.34	0.87	0.18
Power and light	0.65	0.65	0.74	0.86	1.03	0.79	0.04
Lye	0.04	0.07	0.08	0.15	0.07	0.08	0.09
Total	$3.07	$3.79	$4.62	$4.71	$5.86	$4.41	$3.99

Yields by Sun Drying and Dehydration.—Christie's experiments indicate a higher yield by dehydration than in sun drying. A ton of fruit carefully selected for uniformity of size and maturity was divided into two lots which were further sorted into No. 1 and No. 2 fruit by a fresh fruit grader. One lot of each grade was partially dried in the sun, stacked and drying completed by the most approved sun drying methods. One lot of each was dehydrated in a commercially operated air-blast dehydrater. Samples of the dried products were analyzed for moisture content and yields were calculated to a basis of common moisture content with the results given in Table 71.

TABLE 71.—COMPARATIVE YIELDS OF FRENCH PRUNES BY SUN DRYING AND DEHYDRATION

(*After Christie*)

Size	How dried	Drying ratio	Pounds of dry per 100 pounds fresh on 25 per cent moisture basis	Count per pound
No. 1	Sun dried	2.34	42.7	43
No. 1	Dehydrated	2.16	46.3	42
No. 2	Sun dried	1.84	54.2	47
No. 2	Dehydrated	1.82	54.9	43

Dehydration yielded at the rate of 1,012 pounds per green ton, and sun drying 969 pounds, an appreciable difference in yield in favor of dehydration. The quality of the dehydrated prunes was found to be equal to, or better than, that of the sun-dried.

Dehydration of Prunes in Oregon.—In the Pacific Northwest the Oregon tunnel is used for drying prunes at the orchard or in large centrally located plants owned by growers' organizations. The Italian prune, a tart variety, is grown almost exclusively. It is advertised in eastern markets as the "Mistland" tart-sweet prune. The fruit is lye dipped to check the skins and is placed on screen trays which are entered at the upper end of the tunnels at about 100 to 130°F. A temperature of 180 to 190°F. is commonly used and 200°F. is not uncommon near the end of the drying period, resulting in some caramelization.

Variation in temperature in these dryers when wood is used for fuel is very great. A superior product is obtained by drying in carefully controlled forced-draft dehydraters at temperatures not above 150°F.

The efficiency of the Oregon tunnel is much increased by the installation and use of a fan for recirculation of the air, as shown by Wiegand[22] of the Oregon Agricultural College.

Lewis[7] recommends that Italian prunes be dried to a moisture content of 17 to 18 per cent. However, if dried to a very low moisture content in an Oregon tunnel there is great danger of scorching.

Other Fruits.—Persimmons lose all of their astringency ("pucker") when peeled and dehydrated if not previously sulphured. They are sweet and of pleasing flavor.

Raspberries dry quickly and require no preliminary treatment except sorting. The black variety may be successfully dried on a kiln floor but better results are obtained on trays. Temperatures above 145°F. are not desirable.

Strawberries "drip" badly unless drying is started at a temperature of 100 to 110°F. A short period of sulphuring (15 to 20 minutes) improves and fixes their color.

Citrus fruits are dried in limited quantities for use in preparing a flour or meal for flavoring purposes. The whole fruit is sliced and dried "bone dry." It is then ground and is used in this form in limited amounts by bakers and confectioners.

Pickled ripe olives were at one time dehydrated in California but were not in great demand. If pitted before drying, ripe pickled olives yield an excellent dried product for flavoring meat dishes, etc. They possess a mushroom like flavor.

Summary of Dehydration of Fruits.—The following table summarizes recommended methods to be followed in the dehydration of fruits.

Table 72.—Recommended Methods for Dehydration of Various Fruits

(After Cruess and Christie)

Variety of fruit	Pounds per square foot on trays	Hours sulphured	Maximum temperature at end of drying period, °F.	Desirable humidity in tunnel dehydrater at end of drying period, per cent	Drying time by counter current method, hours	Remarks
Apples	2	½	165	5–10	8	Peeled and sliced or cubed
Apricots	2	1	160	10	12	Halves unpeeled
Bananas	1 –2	½	165	5–10	12–18	Peeled, cut in half lengthwise
Cherries:						
Black Tartarian	2 –3	0	170	10–25	8–12	Lye dipped
Royal Anne	2 –3	¼	170	10–25	8–12	Lye dipped
Figs	2 –3	1	160	5	10	One side cut and figs spread open
Grapes:						
Muscat	3½–4	0	160	5	24	Lye dipped
Seedless	3½–4	1	160	5	16	Lye dipped
Wine	3½–4	1	160	5	20	Lye dipped
Loganberries	1½–2	0	160	10–25	10–15	Untreated
Peaches	3	1	150	20–30	24	Not peeled
Peaches	3	1	150	20–30	16	Lye peeled
Pears	3	24	145	30–40	48	Halves unpeeled
Pears	2	½	150	10–20	6	Peeled and sliced
Pears	2	1	150	10	16	Peeled and cored
Prunes:						
Italian	2½–4	0	170	20–30	24	Lye dipped
French	2½–4	0	165	20–30	24	Lye dipped
Imperial	3 –4	0	165	20–30	30–36	Lightly dipped
Raspberries	1½–2	0	170	10–25	8–12	Untreated
Strawberries	1½–2	½	160	10–25	24	Stemmed

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CHAPTER XXII

DEHYDRATION OF VEGETABLES

Unlike fruits, vegetables do not lend themselves well to sun drying. Sun-dried vegetables are tough, unattractive in appearance, bleached in color and of poor flavor. Dehydrated vegetables, on the other hand, are often equal to the canned products in quality.

Vegetables may be grouped into two classes: those that are canned but that can be successfully dehydrated, such as spinach, sweet potatoes, corn, peas, string beans, tomatoes, pumpkin, cabbage and beets; and those which are well adapted to dehydration but which are seldom canned, such as potatoes, turnips, carrots, celery, onions and sprouts.

Comparison with Canned Vegetables.—When compared with the canned products it is found that dehydrated vegetables possess several advantages. They weigh from one-fifth to one-twentieth as much as the canned products and are of from one-half to one-tenth the volume. This results in a great saving in containers and in transportation charges. Their principal disadvantage lies in the fact that they require "refreshing" (soaking) in water several hours before cooking.

Table 73 gives the relative weights of various canned and dehydrated vegetables obtained from 1 ton of the fresh vegetables.

TABLE 73.—RELATIVE WEIGHTS OF CANNED AND DEHYDRATED VEGETABLES FROM 1 TON OF THE FRESH PRODUCTS

(Weights of containers included)
(*After Prescott*)

Vegetable	Weight prepared for canning or dehydration, pounds	Weight canned and packed, pounds	Weight dehydrated and packed, pounds
Corn	750	1,426	465
Peas	1,960	4,291	350
String beans	1,500	3,832	200
Lima beans	800	2,300	250
Tomatoes	1,100	1,763	125
Pumpkin	1,400	2,146	200
Sweet potatoes	1,450	2,250	513
Cabbage	1,450	2,400	215

Present Status.—Since the war the interest in dehydrated vegetables has declined with the possible exceptions of corn and pumpkin. Potato flour has been a standard product for a number of years and is used extensively for mixing with wheat flour in making bread, where it serves as a yeast food, and it is also used as a sizing for cloth. In continental Europe dehydrated vegetables are more popular than in the United States. Precooked ground and compressed vegetables for use in soups are common in Germany and Switzerland. Holland also produces considerable quantities of dehydrated vegetables.

Food Value of Dehydrated Vegetables.—Dehydration does not alter the chemical composition of vegetables except by concentrating all constituents except water. It is believed that there is some loss in the antiscorbutic vitamin C when the cooked fresh vegetable is compared with the same vegetable after dehydration and cooking.

Prescott[17] has compiled analyses of fresh and dehydrated vegetables and a few of his analyses are shown in Table 74.

TABLE 74.—COMPARATIVE FOOD VALUE OF FRESH AND DEHYDRATED VEGETABLES

(After Prescott)

Vegetable	Per cent, water	Per cent, protein	Per cent, total carbohydrates	Fuel value per pound calories	Ratio fuel value of fresh to dehydrated
Cabbage, fresh, edible portion	91.5	1.6	5.6	145	1:10.6
Cabbage, dried	10.0	16.9	59.3	1,536	
Corn, green, edible portion	75.4	3.1	19.7	470	1: 3.7
Corn, dried	10.0	11.3	72.1	1,720	
Peas, green, edible portion	74.6	7.0	16.9	385	1: 3.5
Peas, dried	10.0	24.8	59.8	1,646	
Potatoes, fresh, edible portion	78.3	2.2	18.4	385	1: 4.1
Potatoes, dried	10.0	9.1	76.4	1,598	
Pumpkins, fresh, edible portion	93.1	1.0	5.2	120	1:13.0
Pumpkins, dried	10.0	13.0	67.8	1,565	

Washing.—Root vegetables and tomatoes particularly require thorough washing, for which the rotary tomato washer is generally well suited. The same principles and methods apply in washing vegetables for dehydrating as for canning.

Peeling and Trimming.—Mechanical peelers can be used in the preparation of potatoes and most other root vegetables. A successful type of peeler for this purpose consists of a circular steel cylinder, about 30 inches in width and about 16 inches in depth, the sides and bottom of which are coated with coarse carborundum crystals which act as an abrasive surface. The bottom of the peeler revolves rapidly and rubs the vegetables against the rough surface, thus grating the peels from them. A heavy spray of water washes away the peels.

The peeling is not perfect and considerable hand trimming is necessary. A machine of approximately the above dimensions was found to have a capacity of about 50 pounds of potatoes per charge which was peeled in 45 seconds. The loss in the peeler was about 36 per cent and in trimming about 2 to 3 per cent.

Onions are usually peeled by hand, as the mechanical peeler either breaks the vegetable too much or does not remove the outer dry husks satisfactorily.

Carrots, white potatoes, turnips and parsnips can be peeled satisfactorily in the above type of mechanical peeler. Beets and sweet potatoes are peeled as for canning, by first steaming or cooking in a retort to loosen the skins, followed by hand peeling.

Carrots and sweet potatoes may also be peeled very satisfactorily with boiling 10 per cent lye.

Tomatoes are greatly improved by peeling before dehydration, although it is customary to omit this operation, trimming and slicing constituting the usual procedure.

Peppers and pimientoes are dehydrated without any preliminary treatment other than sorting. Cabbage heads are cored and the outer leaves are removed and discarded, corn is husked as for canning which may be done mechanically. Spinach is trimmed and is then very thoroughly washed as for canning in order to remove sand and insects. String beans and peas are prepared as for canning. Egg plant, pumpkin and okra are usually not peeled.

Slicing, Cubing and Shredding.—Vegetables to be used in soup mixtures are shredded or cubed mechanically after peeling.

Potatoes are either cubed or are sliced to about 1/8 of an inch in thickness. They are sometimes cut in rectangular strips as for French-fried potatoes.

Cabbage is shredded in a sauerkraut slicer or in a rotary type of vegetable slicer.

Blanching and Precooking.—Most vegetables lose their color and flavor rapidly after drying, unless they are blanched in steam or boiling water before drying. Blanching destroys the enzymes responsible for a great deal of the undesirable change occurring in dried vegetables, hastens the rate of drying in many cases and arrests changes which tend to

make the vegetables tough and difficult to cook. It also intensifies and fixes the color in some cases. Some vegetables, however, *e.g.*, tomatoes, onions, spinach and peppers, are not improved by blanching.

Cabbage should be blanched in a boiling dilute sodium bicarbonate solution (approximately 1 per cent) for about 1 minute. The bicarbonate intensifies and fixes the natural color and improves the keeping quality of the dehydrated product.

Nichols and Gross[6] found that carrots gave the best dehydrated product when blanched in a boiling 2 per cent salt solution for 2 to 4 minutes.

Celery does not require blanching. Corn should be blanched on the cob after husking for 5 to 10 minutes to "set the milk." Okra should be sliced and blanched about 2 minutes in boiling water; peas and string beans should be blanched in boiling water 3 to 10 minutes, depending upon their maturity. Potatoes are usually blanched in steam, but more uniform results and less overcooking of the edges of the pieces result from blanching in water at 180 to 190°F. for 4 minutes or in boiling water about 3 minutes. Blanching gelatinizes the loose starch granules on the surface of the pieces and causes them to stick together or to stick to the trays and the blanched potatoes should, therefore, be rinsed free of this starchy material in cold water before traying.

Sweet potatoes may be treated in the same manner as Irish potatoes, but usually the whole unpeeled potatoes are steamed until the skin will slip readily and until the vegetables are cooked through but not mealy, when they may be peeled and cubed or sliced.

Pumpkin is not usually blanched before drying for flour but its color and keeping quality are improved by blanching in steam on the trays for 2 or 3 minutes.

Spinach and other greens become unduly brittle and tomatoes soften badly if blanched. Turnips and parsnips are blanched as described above for carrots.

Blanching Equipment.—In general, blanching in water permits of more careful regulation than blanching in steam, although the loss in soluble solids is greater in water than in steam blanching. Steam blanchers are of two types: one, a cabinet fitted with perforated steam pipes, the other, an enclosed steam box similar in appearance to an exhaust box, through which the vegetables pass on trays and conveyor or on a woven metal cloth conveyor (see Fig. 90).

Water blanching may be made continuous by use of a conveyor or may be done in small tanks of boiling water with baskets.

Sulphuring.—Potatoes to be dried for making flour for the textile industry are sulphured; other vegetables should not be sulphured.

Trays.—Screen trays of ⅛-inch mesh are satisfactory for vegetables. Slat trays are not so suitable because of loss of the dried products through

the spaces between slats. Vegetables do not react upon the metal as vigorously as fruits, because they are less acid and less juicy.

Temperatures of Drying.—Most vegetables give up their moisture readily and on this account the parallel current system of drying can be used to advantage. An initial temperature of 180 to 185°F. and a finishing temperature of 140 to 145°F. can be used and very rapid drying rates obtained. The finishing temperature should not exceed 150°F. for most vegetables. If the counter current method is used, high air velocity may be used to reduce the drying time.

Fig. 90.—Large steam heated blancher for vegetables on trays and small blanching tanks and baskets.

Drying Times.—Most vegetables, as prepared and dried commercially, dry in less then 6 hours. Spinach can be dried in 2 hours and potatoes usually require 6 to 8 hours by the counter current system.

Moisture Content.—Nichols and others have found that the moisture content of dehydrated vegetables must be less than 8 per cent and preferably less than 6 per cent in order to retard harmful enzymatic changes in color and flavor during storage after dehydration. Unblanched vegetables deteriorate more rapidly than the blanched products because of acceleration by oxidizing enzymes.

Above 20 per cent moisture, dehydrated vegetables will generally mold in sealed containers. The upper limit for fruits is about 25 per cent. The sugar in dried fruits exerts some preservative action and its lower concentration in dried vegetables accounts for their greater susceptibility to molding.

DEHYDRATION OF VARIOUS VEGETABLES

In order that the description of the preparation and drying of the more important vegetables may be as complete as space permits, the following additional information is given.

Potato Flour for Use in Baking.—In preparing potato flour by the flake process, for use in baking, the following steps are involved: The potatoes are first washed thoroughly, then peeled mechanically and trimmed by hand, if to be used for the best grade flour, although peeling is sometimes omitted.

They are cooked in a retort under 15 pounds steam pressure for 15 to 25 minutes, which reduces them to a mealy consistency. They are then passed between steam-heated steel cylinders, which have a smooth surface and revolve closely together. Steam at about 60 pounds pressure is used in the cylinders. The potatoes are compressed to a very thin layer and dried bone dry by contact with the hot surface of the cylinders. Mechanical scrapers remove the dried product, which falls in flake-like form to a conveyor.

The flakes are ground at once and bolted to yield a flour, which compares favorably with wheat flour in food value, although it is somewhat lower in protein.

The flake process is used extensively in Europe, but there are only a few plants in America.

Flour from Sulphured Potatoes.—In a California plant during the World War the following method was used in drying potatoes for flour for use in the textile industry. The potatoes were soaked to loosen adhering soil and then thoroughly washed, peeled and sliced mechanically. The sliced potatoes were sulphured on a wooden slat conveyor in an enclosed rectangular box and were then spread and dried at 200°F. on the belt of a three-conveyor air-blast dehydrater. The dried pieces were then ground and bolted.

Prescott and Mangels[3] attempted to prepare sweet potato flour by the flake process but found that it was hygroscopic and soon became lumpy and of little value as flour.

Dehydration of Potatoes for Table Use.—During preparation for dehydration the potatoes are washed, sorted, mechanically peeled and are carefully trimmed by hand. They may then be sliced about $\frac{3}{16}$ of an inch thick or cubed. They are blanched from 2 to 5 minutes in water at 180 to 212°F. and rinsed in cold water.

Blanched potatoes case-harden if the relative humidity during drying is very low, and at temperatures above 150°F. the color is apt to become reddish-brown.

Potatoes, properly prepared and dehydrated, should be white or very light yellow in color and translucent, and should be dried until hard and brittle. When broken between the fingers the fracture should be sharp and the interior of the pieces should be flinty and not mealy. The drying ratio is from 5 to 7:1.

Sweet Potatoes.—The potatoes are peeled as for canning. They may be dried in a number of different forms, *e.g.*, cut in halves or quarters length-

wise to be used for baking, or sliced for frying, or whole for baking, boiling, etc. They are not as sensitive as white potatoes to heat and may be safely dried at 175°F.

The drying ratio is about 3.5:1, a higher yield of dried product than from any other common vegetable. They should be dried until brittle, otherwise molding is apt to occur during storage.

Onions.—Onions must be trimmed and peeled by hand and should be cut in very thin pieces because of the tendency of thick pieces to case-harden, to dry very slowly and to darken.

Blanching is undesirable, because it causes the onions to stick to the trays and does not improve their appearance. Immersion of the sliced onions in cold 5 per cent salt solution for 3 to 5 minutes before drying reduces their tendency to darken during drying and later in storage.

A temperature of 140°F. should not be exceeded during dehydration, because of darkening of the color and loss of flavor at higher temperatures. The drying ratio is from 10:1 to 15:1.

Dehydrated onions can be ground to a flour suitable for flavoring various dishes, such as stews, gravies, etc.

Carrots and Other Root Vegetables.—These vegetables include carrots, turnips, beets and parsnips. They are prepared for drying as described in the paragraphs on preparation and blanching.

They may be dried rapidly, as they will withstand relatively high temperatures (165 to 175°F.), and should be dried until hard and brittle.

Pumpkin.—Pumpkin and squash are dehydrated for the preparation of "pumpkin flour," a finely ground, coarsely bolted mixture of the two vegetables. In California a mixture of Connecticut field pumpkin and Boston Marrow squash is used.

The pumpkins and squash are cut in half with large knives and the seeds and seed cavity pulp removed. The unpeeled halves are sliced or shredded in a silage cutter or other heavily constructed cutting machine into pieces about ¼ inch thick. In most factories the pumpkin and squash are not blanched, but the color is greatly improved if the slices are steamed on the trays until heated through.

The vegetables are dried until very dry, less than 6 per cent moisture, and are ground in an attrition mill before they can absorb moisture and become leathery. The ground product is bolted or screened to remove the coarse particles, which are reground. The resulting flour is packed in small envelopes for household use or in large friction top cans for bakery, restaurant and hotel use for pies.

Tomatoes.—Tomatoes may be dried in sliced form unpeeled, but the quality is much improved by peeling before drying in the same manner as for canning.

Slices should be about ¼ inch thick and no blanching is required.

Temperatures below 150°F. should be used, as the slices darken at higher temperatures. They should be dried until the pieces show no moisture when pressed between the fingers, or until the slices will break crisply on bending.

The dried product may be packed in the form in which it comes from the trays, it may be ground to a meal which can be used in soups, etc., without preliminary soaking or the ground product may be pressed into bricks. The drying ratio is about 16:1.

Peppers and Pimientos.—Dried hot peppers are used in large quantities by the Mexican population of the southwestern United States and Mexico. A considerable quantity is dried for the manufacture of paprika, a sweet pepper powder for use on the table and in cooking. A great deal of the dried, hot red peppers are ground for packing as cayenne pepper.

The bags of well-ripened peppers are emptied on trays made of fine-mesh (about 1-inch) chicken netting attached to a frame of 1- by 3-inch material, the usual tray being about 2½ by 5 feet. The peppers are sorted to remove green and spoiled specimens. They are dried in natural-draft, gas-heated driers at 130 to 160°F., a drying time of 3 to 5 days being required. The peppers are dried until brittle and until the seeds and pulpy portions are thoroughly dried.

Grinding of sweet peppers for paprika and of hot peppers for cayenne pepper is done in centrally located mills. The peppers must be dried to a very low moisture content and milled very shortly after drying, as they become tough with absorption of moisture.

Sweet Corn.—Corn has been dried in the sun or in ovens by housewives for many years, but its commercial-scale drying is of recent development. Properly dehydrated corn when soaked and cooked compares favorably with canned corn in quality and is cheaper. Only young tender ears of the best table varieties, such as the Country Gentleman and Golden Bantam, should be used for drying.

The ears are husked as for canning and the corn is blanched on the cob in steam or boiling water for about 5 to 10 minutes. It is silked as for canning, cut from the cob and spread on screen trays and dehydrated to a low moisture content. The dried product is subject to attack by insects and should be packed at once after drying or should be fumigated thoroughly before packing to destroy eggs of insects, such as the Mediterranean meal moth, etc.

Corn dries very rapidly and will withstand a finishing temperature of 150°F.

Several factories in the eastern United States have been successful in dehydrating and marketing sweet corn.

String Beans.—Dehydrated string beans have been one of the most popular vegetables dehydrated commercially. Dehydration intensifies

any toughness the beans may originally possess and makes it imperative that only very tender beans be dehydrated.

The beans are snipped as for canning, are broken into short lengths and blanched in boiling water for 5 to 10 minutes, depending on the size and maturity of the beans. Caldwell[1] recommends the addition of a small amount of sodium bicarbonate (about ½ of 1 per cent) to the blanching water to darken and fix the color.

The beans should be spread in a shallow layer on the trays; a deep layer dries very slowly and unevenly. They should be dried until both the pods and the beans in the pods are brittle. The drying ratio for young string beans is about 10:1.

Peas.—Peas for dehydration must be even less mature than for canning, because of the tendency of starchy peas to become tough-skinned and mealy during drying. The wrinkled varieties high in sugar content are much to be preferred to the starchy, smooth-skinned varieties.

The vines may be harvested as for canning and the peas separated from the pods and vines in the usual pea vining machines (see chapters on vegetable canning).

The peas are blanched in boiling water as for canning, for 2 to 10 minutes, depending on maturity, and spread on trays direct from the blancher in a layer about ¾ of an inch deep. The finishing temperature should not exceed 145°F., since high temperatures cause browning and loss of flavor. The center of the pea dries slowly, therefore peas should be dried until entirely crisp.

Spinach.—Spinach requires only trimming, sorting and very thorough washing before drying. Blanching is not necessary or desirable. The washed leaves may be placed in a deep layer on the trays, provided air flow between trays is not seriously impeded.

The leaves dry very rapidly and relatively high temperatures (175°F.) can be used. The stems because of their greater thickness dry more slowly than the leaves. The spinach should be dried to less than 6 per cent moisture and packed at once in packages which resist penetration of moisture. Spinach may be ground to a powder or pressed into briquettes if desired. The drying ratio is approximately 12 to 15:1.

Cabbage.—Cabbage is dehydrated quite extensively in Europe, where it is often packed in briquette form. The cabbage heads are cored, the outer leaves removed and the heads shredded in a sauerkraut slicer. The cut cabbage should be blanched about 1 minute in boiling 1 per cent sodium bicarbonate solution, which intensifies and sets the color. A temperature of 145°F. should not be exceeded during drying. The cabbage is dried until crisp and should be packed if possible in moistureproof containers. On exposure to air it darkens slowly and deteriorates in flavor. Undoubtedly vacuum-sealed cans would greatly improve its keeping quality. The drying ratio is approximately 15:1.

Cauliflower and Sprouts.—Brussels sprouts and cauliflower give fairly satisfactory dehydrated products. They are prepared as for cooking for the table, cauliflower heads, in addition, being broken or cut in smaller pieces. They are blanched in steam or boiling water 4 to 5 minutes. The temperature of drying should not exceed 140°F. because of their tendency to darken.

Okra.—Small pods may be dried whole and large pods should be cut lengthwise in halves or quarters or crosswise in circular pieces. Blanching in boiling water from 2 to 5 minutes is advisable, followed by rinsing in cold water to remove the gelatinous coating formed in blanching. The finishing temperature should not exceed 140°F. and the drying ratio is approximately 10:1.

Celery.—Both the leaves and stalks of this vegetable may be dried and used for the flavoring of soups, stews, etc., or for the preparation of powdered celery or celery salt. Only tender stalks relatively free from "strings" should be used. The stalks are trimmed, washed and sliced. Blanching renders the product more tender, 2 to 3 minutes in boiling water being sufficient. Celery leaves may be placed on trays separate from the sliced stalks and require no blanching. The drying temperature should not exceed 140°F.

Rhubarb.—Rhubarb is grown quite extensively in many states, especially in proximity to large cities. In the early spring, before fresh fruits and summer vegetables are available, rhubarb brings very profitable returns in local markets. However, the demand and, consequently, the price soon decrease and it oftens happens that much of the later rhubarb is never marketed. For dehydration the stalks are trimmed, washed and cut into short lengths, which are spread and dried on trays at not above 175°F. The drying ratio is 13 to 15:1.

Garlic.—Garlic powder is made by grinding dehydrated garlic, and when mixed with cornstarch is a product of considerable merit. The garlic "buttons" are dehydrated without blanching and when bone dry these are finely ground and mixed with starch or flour to "dilute" the garlic flavor. The powder retains its flavor indefinitely and is excellent for flavoring gravies, stews, spaghetti, etc.

Horse-radish.—This vegetable retains its pungency when dehydrated. The radish is washed, trimmed, grated and dried at a moderate temperature, 140 to 150°F. It can be refreshed in water and used in the same manner as the fresh product.

Soup Mixtures.—Soup mixtures were used extensively by armies in the field during the World War.

The pieces should be cut very thin or in small cubes or shreds so that they will cook quickly and should be thoroughly blanched before drying.

Various mixtures have been made. One recommended by Caldwell[2] is: potatoes 20 parts, turnips 20 parts, peas 20 parts, onions 6 parts and

17 parts each of carrots and beans. Flaked, cooked, dry white beans are used by one company to give a thicker consistency to the soup and make a valuable addition nutritionally, because of their high protein content. Most soup mixtures contain celery in addition to the ingredients recommended by Caldwell and tomato powder or shreds is an improvement. Turnips tend to become brown on storage and can, if the soup mixture is not to be used promptly, be eliminated.

In preparing soup mixtures it must be borne in mind that, since the mixture must subsequently be soaked and cooked as a unit, only such vegetables as absorb water and become cooked at approximately the same rate should be mixed. Peas and beans absorb water more slowly than the other vegetables named above unless they are cooked until almost ready for serving before they are dehydrated.

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CHAPTER XXIII

THE PACKING OF DRIED FRUITS AND VEGETABLES

The packing of sun-dried fruits is an industry separate and distinct from that of drying, although dehydrated fruits are in many cases packed in the same plants in which they are dried.

Dehydrated vegetables are generally packed in the same building in which they are dried.

Importance of Dried Fruit Packing Industry.—Table 55 shows the growth of the dried fruit industry in California from 1903 to 1921.

Approximately 15,000 tons per year of dried figs are packed in Smyrna. Greece, Asia Minor and Spain pack and export large quantities of raisins and Egypt, northern Africa and Asia Minor produce most of the world's supply of dates. These fruits are in part packed ready for use, but much of the crop is shipped in bulk to America and Europe and is there processed and packed in cartons or boxes.

Oregon produces approximately 25,000 tons of dried prunes per year, while New York is the largest producer of dried apples.

DRIED FRUIT INSECTS

Insects cause in the aggregate enormous damage to dried fruits and vegetables and heavy financial losses to growers, packers, distributors and consumers. Many of the operations of packing dried fruits and vegetables have for their purpose the destruction of insects and insect eggs and the exclusion of insects from the packed products.

General Types of Infestation.—Three groups of insects are of importance in causing damage to dried fruits and vegetables. The most important group is that of the moths, including the Indian meal moth (*Plodia interpunctella* Hubn) and the fig moth (*Ephestia cautella* Walk).

Beetles are second in importance, of which the most common in dried fruits are the dried fruit beetle (*Carpophilus hemipterus* L.), the saw-toothed grain beetle (*Silvanus surinamensis* L.), the foreign grain beetle (*Cathartus advena*, Waltl) and a fungous beetle (*Henoticus serratus* Gyll).

The third group of insects includes two sugar mites (*Tyroglyphus siro* Gerv. and *T. longior Gerv.*). These mites are of very small size, scarcely distinguishable to the unaided eye.

The Indian Meal Moth (*Plodia interpunctella* Hubn).—Essig[2] comments as follows on this insect:

This insect is widely distributed and occurs not only in dried fruits but also in all cereal products, dry grains, seeds, nuts and many other foods. The larvae are yellowish-white and average about 1 inch in length. They are profuse web spinners and their webs, covering the fruit and containers, are more injurious to the appearance of the dried products than any other form of damage caused by this insect.

The fully grown larvae enclose themselves in small white cocoons about ½ inch long. The chrysalids are brown.

The moths average from ½ to ¾ of an inch in length. They are readily distinguished from other moths by the distinctive two-colored pattern of silvery-gray and bronze, the anterior portion of the wings being silvery and the posterior half bronze or copper colored.

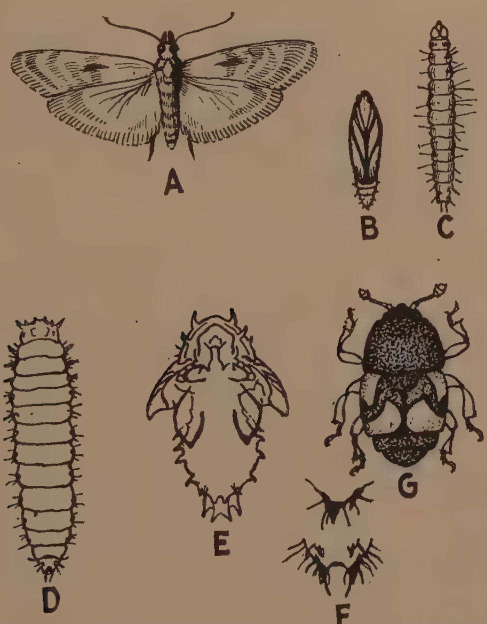

Fig. 91.—Common dried fruit insects. *A*, adult of Mediterranean meal moth; *B*, chrysalis; *C*, larva; *D*, larva of dried fruit beetle; *E*, pupa; *F*, posterior appendages; *G*, adult beetle. (*A, B, and C, after Chittenden; D, E, F and G, after Essig*).

The very minute eggs are laid on or as near the dried products as possible, generally at night. The newly hatched larvae are very small and very active. They have a remarkable ability for locating dried fruit and will enter packages through very small cracks or other openings.

The remarkable reproductive power of this insect accounts for the sudden appearance in packing houses of enormous numbers of the larvae.

The moth is often found in dried fruit or refuse held over from the previous season. As a rule, public warehouses are infested with this insect and susceptible foods stored in such places invariably become

infested. The appearance of this insect at various stages is shown in Fig. 91.

The Fig Moth (*Ephestia cautella* Walk) is very similar in appearance and habits to the Indian meal moth.

The Dried Fruit Beetle (*Carpophilus hemipterus* Linn.).—After Essig.[2]

This is the most injurious of the beetles that infest dried foods. The larvae are small and whitish-yellow and are distinguished from the caterpillars of the dried fruit moths by the fact that they possess only three pairs of true legs, whereas the caterpillars possess three pairs of true legs and three pairs of fleshy prolegs.

The adults are short and robust, scarcely ¼ of an inch long. They are black in color, with reddish- or cinnamon-brown posterior portions. The larvae reduce the fruit to a fine powder or "frass," which is the excrement.

This insect ordinarily infests the fruit (particularly figs) while it is still in the field or dry yard. It is carried to the warehouses and packing houses in the fruit, where it thoroughly infests the premises. It is very active in laying eggs on figs during cooling of the fruit after processing (see Fig. 91).

The insect has marked ability to locate dried fruit and, like the Indian meal moth, reproduces with astonishing rapidity.

The Saw-toothed Grain Beetle (*Silvanus surinamensis* Linn.).—After Essig.[2]

Although of somewhat less importance than the dried fruit beetle, the saw-toothed grain beetle is, nevertheless, capable of causing extensive damage to dried fruits and vegetables. The larvae are small, about ¼ of an inch long and of whitish color. The adults are brown or blackish beetles ¼ of an inch long, slender and with saw-like teeth along the sides of the prothorax (neck). These teeth can be seen without a hand lens. They are particularly destructive to figs, not only destroying the inside of the figs, but also boring minute holes through the skins.

Clean Premises.—The packing house should be kept clean and it is good practice to clean the plant thoroughly at the start of the packing season. Fruit held over from the previous season or refuse fruit must be closely inspected and if found infested must be destroyed or fumigated or otherwise treated to eliminate the insects. It is good practice, where the walls are tight enough, to fumigate the plant throughout at the start of the season. Graders, conveyors etc., must be thoroughly cleansed of webs, pupae, dried fruit, etc.

Fumigation.—Fumigation with poisonous gas or vapor is one of the commonest methods of destroying insects in foods. The room used for this purpose must be comparatively gas tight, one with concrete walls, floor and ceiling, with no window and with a beveled, ice-chest type of door is desirable. In the absence of such a room heavy canvas may be thrown over the bins or piles of fruit.

Fumigation thoroughly applied kills the insects in all stages of development, including the eggs, and does not injure the flavor, color or texture of the fruit but requires experience and great care. Carbon bisulphide and hydrocyanic acid gas are the two fumigants generally used. The former is very inflammable and the latter deadly poisonous.

Carbon Bisulphide.—For general purposes in either large or small spaces carbon bisulphide should be used at the rate of 20 pounds* per 1,000 cubic feet of air space. In handling this material it must be remembered that the gas is heavier than air and will settle to the bottom of a room or house. This is a great advantage in fumigating heavy dense masses, like raisins and bins and boxes of fruit, for if the carbon bisulphide is placed in shallow containers upon the top it will gradually work its way through to the bottom. Where the containers for the liquid cannot be placed directly upon the fruit or where fumigation is used in a large house, the containers may be placed on boxes, stepladders, etc., in order to raise them as far above the floor as possible. The *liquid is highly inflammable and the gas is explosive when mixed with air.* Therefore, great care should be taken in keeping flames away from buildings in which carbon bisulphide is used as a fumigant. Where fire insurance is involved it is advisable to obtain from fire underwriters the rules governing the use of inflammable fumigants.

Hydrocyanic Acid Gas.—In the past this gas has usually been obtained by the pot-generating method, which is still extensively used for such purposes as we are discussing. This fumigant should only be handled by experienced persons because of its intensely poisonous nature.

Vacuum Fumigation.—Considerable experimentation has been done in recent years by the federal and state authorities with a vacuum fumigator constructed of steel plate and used as a fumigating chamber from which the air is drawn and vacuum conditions created. Into this space the fumigants are drawn and come in intimate contact with the materials placed inside for treatment.

The advantages of such an apparatus include thorough penetration of the vapors into the densest food materials, rapidity of action and safety of operation. It can be applied to packed as well as to bulk goods.

The product is generally treated in the gas for 1 hour.

Although carbon bisulphide is the fumigant generally used, it may be replaced with hydrocyanic acid gas or by sulphur dioxide. Vacuum fumigation has been adopted by most of the large packers of dried vegetables as the most convenient and most dependable method of destroying insects in the packed products.

Sulphur Dioxide.—Apricots during the packing process are wet with water and are treated 4 to 12 hours in the fumes of burning sulphur.

* A pint of carbon bisulphide weighs about 1.3 pounds. It would therefore require about 2 gallons per 1,000 cubic feet.

Parker[3] has found that this treatment destroys all insect life in the fruit. It can only be applied to those fruits normally sold in the sulphured state, such as pears, peaches and apricots.

Heat as an Insecticide.—In the processing of prunes, "practically peeled" dried peaches, seeded raisins and dried figs the fruits are passed through boiling water or dilute solutions of salt or sodium bicarbonate. The fruits are thoroughly cleansed and all insect life killed by heat.

Several packing houses treat dehydrated vegetables by dry heat for several hours at 145 to 150°F., a treatment found convenient and very effective. The dry heat process may be made continuous by use of superimposed screen conveyors placed in a chamber heated by steam coils or gas, or by a current of heated air. Any good dehydrater can be used for the purpose. A temperature of 180°F. can be used for products not injured at this temperature and the time of treatment shortened to a few minutes.

Products sterilized by heat must be packed immediately to avoid reinfestation, unless stored in an insectproof room. The containers, also, must be sterilized, as they very frequently contain insect eggs.

Insectproof Packing Rooms.—Packing rooms should be of tight construction, so that they may be fumigated occasionally. Doors and windows must be screened to exclude insects. If these precautions are taken much insect infestation in packed goods may be avoided.

Insectproof Packages.—Tin cans, either friction top or hermetically sealed, are proof against insects and are ideal containers for fruits and vegetables shipped to or through the tropics, or to warm, humid districts, such as the southern United States. They have not been generally adopted because of their relatively high cost and because the public is accustomed to purchasing dried products in paper cartons or boxes and is slow to become accustomed to new styles of containers.

Parker[3] has found that the usual dried fruit boxes and cartons are not proof against insects. He has, however, developed a process of wrapping small cartons (1- to 10-pound sizes) in wax paper, as is done with cereal cartons, to exclude insects effectively. He recommends a well-made and sealed inner seal for large cartons and boxes. Sealed packages also reduce the tendency of dried fruits to lose moisture and become sugary on the surface and prevent excessive absorption of moisture by dried vegetables.

Fruit which is treated in boiling water or steam before packing must be allowed to dry on the surface before being placed in wrapped cartons, otherwise molding may occur.

Effect of Cold Storage on Insects.—It has been found by de Ong of the University of California that the development of insects is prevented if dried fruits are placed in ordinary commercial cold storage warehouses at 36 to 50°F. The insects remain dormant, but are not killed

unless the storage is prolonged 3 to 4 months. This means of storage is used extensively during the summer months in large distributing centers, such as New York and Chicago.

PACKING DRIED APPLES

Dried apples are usually packed by those who dry them and in the same building in which the dryer is located.

Grading.—Five grades are generally recognized in the trade, as follows:

Extra Fancy.—Rings of fairly uniform size; uniform white color; clean; free from skins, cores, stems, bruised or rotten spots, worm holes or screenings.

Fancy.—Rings of fairly uniform size; uniform white or very light yellow color; clean; almost free from skins, cores, stems, bruised spots, worm holes or screenings.

Extra Choice.—Rings of fairly uniform size; white or light yellow color; not more than 25 per cent of pieces showing skins, cores, stems, bruised or rotten spots or worm holes; fairly free from screenings.

Choice.—Rings of white, yellow or light brown color; not more than 50 per cent of pieces showing skins, cores, stems, bruised spots, worm holes; may contain a noticeable amount of screenings.

Standard.—Brown color; large percentage of pieces showing skins, cores, stems, bruised spots and considerable screenings present.

According to Beattie and Gould[1] only three grades are recognized in some apple drying districts. These grades are Fancy, Choice and Prime. Fancy corresponds to Extra Fancy in the above list, Choice to Fancy and Prime corresponds to Choice. The fruit not suitable for the Prime grade is cull or substandard and should be used only for by-products.

Curing and Processing.—Dried apples are stored in bins or heaps on the floor and are generally shoveled over several times during curing. It is customary in many plants to overdry the apples slightly and to return water in the pile by sprinkling and shoveling over. Unless the addition of water is carefully controlled by frequent analyses there is danger of addition of so much water that the apples will spoil in the package or will exceed the government standard of 24 per cent for moisture content.

The moisture content can be determined fairly accurately by drying a 10-gram sample for exactly 4 hours at 200 to 212°F. (92 to 100°C.) in a water-jacketed oven, although the official method consists in drying a 10-gram sample in vacuo at 29 inches mercury and 70°C. (158°F.) for exactly 12 hours.

Packing.—Dried apples are in suitable condition for packing when they have passed through the curing period and the individual pieces have all acquired a uniform moisture content. This is determined by their appearance and texture.

Dried apples are usually marketed in 50-pound boxes. The side of the box intended for the top is packed first, as in the packing of fresh fruit in barrels, and the pieces for the first layer are therefore carefully selected perfect rings. They are faced very carefully with the rings overlapping each other in rows lengthwise of the box on a lining of paraffined paper.

After facing, the box is filled, the contents being firmly packed in with a press made for the purpose and the box is weighed to insure full measure. The cover (which then becomes the bottom) is then nailed on.

Cubed Apples.—Cubed apples are generally packed in 8- or 16-ounce insectproof cardboard cartons.

PACKING DRIED APRICOTS

The process of preparing dried apricots for packing is very simple, and elaborate equipment is not necessary or generally used.

Receiving and Sweating.—The apricots are delivered to the packing house in sacks or in lug boxes and are then stored in large bins to undergo equalization of moisture and to await final processing and packing.

In California the grower's fruit is often sampled as received and he is paid according to the quality and size of the fruit. The fruit should not contain more than 15 to 16 per cent moisture on delivery.

Quality Grades.—In the packing houses of the Prune and Apricot Growers' Association of California, five quality grades are made. These are: Sunsweet quality, which is the best fruit only; Growers' Brand, sound fruit of good quality free from black or other off-quality specimens; Number One Slabs, equal to Growers' or Sunsweet quality in color and flavor, but flat and thin because of over-ripeness; Number Two Slabs, slabs which may contain specimens of off-color; and finally culls, including all unmerchantable fruit.

Size Grading.—Apricots are often size-graded before storage, because the fruit then moves freely on the screens and is not matted.

The grader consists of a long vibrating screen made up of sections with holes of different diameters. The grader is very similar in appearance to that used for peeled peaches and shown in Fig. 12. The following size grades are made.

1. Extra Fancy, over $\frac{48}{32}$ of an inch in diameter.
2. Fancy, $\frac{48}{32}$ of an inch in diameter.
3. Extra Choice, $\frac{40}{32}$ of an inch in diameter.
4. Choice, $\frac{32}{32}$ of an inch in diameter.
5. Standard, below $\frac{32}{32}$ of an inch in diameter.

These size grades apply to both Sunsweet and Growers' Brand qualities of apricots.

The graded fruit falls into portable boxes or large wheelbarrows, in which they are transferred to the storage bins or to the processor.

Processing.—The fruit passes first over a vibrating screen to remove leaves, stems and other refuse and to break up lumps of matted fruit; then through a small tank of cold water to remove dust, to wet the fruit to facilitate absorption of sulphur fumes and to render the pieces more pliable.

They then pass beneath sprays of water on a vibrating screen and pass over the end of the screen to 6- by 3-foot wooden trays. The fruit is spread 2 to 3 inches deep on the trays, and the trays are stacked in a staggered position on cars. In processing, 10 to 12 per cent moisture is absorbed.

Sulphuring.—The trays of fruit are placed in sulphur houses and allowed to remain in the fumes of burning sulphur overnight for the purpose of destroying insect eggs and of impregnating the fruit with enough sulphurous acid to prevent darkening of color and fermentation or molding in the final packages.

Boxing and Pressing.—The fruit is generally packed in 25- and 50-pound boxes, from an overhead storage hopper and spout, and the filled boxes carefully weighed.

The fruit is pressed into the boxes by means of a hand operated plunger or by means of a continuous, mechanical pressing device.

Cartons holding 2, 3 and 5 pounds of dried apricots are also being packed in increasing quantities.

Prices According to Grade.—The price paid for dried apricots varies according to size and quality. The following prices paid by the Association for the 1920 deliveries are typical.

Sunsweet Quality	Cents	Growers' Brand Quality	Cents
Choice	24	Choice	22½
Extra Choice	26	Extra Choice	24½
Fancy	28	Fancy	26½
Extra Fancy	30	First Quality Standards	18
Fancy Moorparks	30	Slabs	20
Extra Fancy Moorparks	33		

PACKING DRIED FIGS

The basic principles and practices of fig packing are similar in the United States and Asia Minor, although in America labor-saving machinery is used to a greater extent.

Grading.—Figs are graded for size by graders similar to those used for apricots. The following sizes are recognized in California:

A. Black Figs (Mission Variety):
1. Fancy, over $^{34}/_{32}$ of an inch in diameter.
2. Choice, $^{34}/_{32}$ of an inch in diameter.
3. Standard, $^{28}/_{32}$ of an inch in diameter.

B. White Figs (Calimyrna and Adriatic):

1. Fancy, over $^{42}\!/_{32}$ of an inch in diameter.
2. Choice, $^{42}\!/_{32}$ of an inch in diameter.
3. Standard, $^{34}\!/_{32}$ of an inch in diameter.

Grading is done as soon as the figs are received at the packing house and before binning and storage.

Dipping.—Before packing, figs are treated in a boiling dilute salt solution. Parker[3] gives the following formula for the usual fig dipping solution: salt, 50 pounds; soda ($NaHCO_3$), 3 to 4 pounds; and water, 150 gallons. The figs are carried through the boiling solution on a conveyor in perforated sheet metal buckets, the usual time of immersion being 45 to 90 seconds, depending upon the water content of the figs and the variety.

Dipping destroys insect life, softens the skins, renders the figs pliable and incidentally increases their weight.

Brick Pack.—The figs are placed before women workers who slit one side of each fig from the stem to the eye with a sharp knife. The fig is then rolled between the thumb and fingers and flattened out in such a manner that the cheeks are spread widely apart and the stem concealed. Spoiled fruit, such as that containing smut, is discarded. The figs are spread to such width that they will fit snugly into small forms made of hard wood and these forms when full are placed beneath a press which compacts the figs into bricks. These are then removed from the forms, wrapped in waxed paper and a lithographed label attached around the brick lengthwise.

The bricks are prepared from Extra Choice and Fancy fruit and are of 4-, 6-, 8-, 12- and 16-ounce sizes. The best grades are packed in lithographed cartons.

Bulk Pack.—Figs which are not satisfactory for bricks are packed in 25- or 50-pound boxes for the baking and biscuit trade or are used for fig meat and a confection base.

Fig Meat.—Small figs and figs of sound quality but unsuitable for bricks are now made into fig meat, a ground and sweetened fig product packed in cartons for the use of confectioners, bakers and housewives. The figs are first passed through a machine which shreds them coarsely but leaves the figs hanging together. The torn figs are conveyed by a belt before girls who remove spoiled fruit.

The sound figs are then ground in a meat chopper and mixed with cane sugar or heavy syrup and citric acid. The sugar improves the flavor and texture. The "meat" is formed into bricks of 12- or 16-ounce size, wrapped in waxed paper and packed in lithographed cartons. It is an excellent confection base, cake filling, pie filling, etc., and provides an important outlet for small figs.

Fancy Packs.—Much of the large fruit is used for special packs. The figs immediately after dipping are "pulled," *i.e.*, manipulated with the hands until soft and pliable and formed into the desired shapes.

Circular boxes are often used as containers, the figs being packed in concentric rings. Usually the surface layer of such packs consists of black and white figs arranged in an attractive pattern.

Layer raisins, peeled dried peaches, nuts and figs are employed in making up "Christmas boxes" holding about 10 pounds each.

Packing Imported Figs.—Large quantities of figs from Mediterranean countries are imported to the United States and packed in New York and other large cities.

Fig "Smut."—The white varieties of dried figs, Smyrna (Calimyrna) and Adriatic, often contain a profuse growth of black mold spores. Infection occurs in the orchard and most of the growth probably occurs before the fruit reaches the packing house. It is practically impossible to identify figs containing this mold unless the figs are cut or torn open. The Mission fig is not affected by the sooty mold, probably because its "eye" is sealed against entrance of the organism. Most white figs are cut open as described above before packing, to permit removal of moldy figs.

PACKING DRIED PEACHES

Sun-dried peaches are packed in two forms: unpeeled and "practically peeled." In California most of the dried peach crop is packed by the California Peach and Fig Growers' Association, a cooperative organization with headquarters at Fresno.

Grading and Storing.—The peaches are graded for size on mechanical graders, as described elsewhere for apricots, and the grower is paid according to the amounts of each size delivered. The size grades are:

1. Extra Fancy, over $^{58}/_{32}$ of an inch in diameter.
2. Fancy, $^{58}/_{32}$ of an inch in diameter.
3. Extra Choice, $^{50}/_{32}$ of an inch in diameter.
4. Choice, $^{42}/_{32}$ of an inch in diameter.
5. Standard, $^{34}/_{32}$ of an inch in diameter.

Dried peaches are divided into two general classes, namely "Muirs" and "Yellows," the latter term including several yellow-fleshed, freestone varieties, principally the Lovell and Elberta. The Muir peach is preferred to other varieties on account of its color, flavor and sweetness.

The graded peaches are stored in bins until they are to be packed. The moisture content at the time of binning should not exceed 16 per cent, in order that matting and crushing of the fruit will not occur.

Packing Unpeeled Peaches.—Unpeeled peaches are processed and packed in the same manner as described elsewhere for apricots.

"Practically Peeled" Peaches.—This process was developed by W. H. Beekhius, factory manager of the Peach and Fig Growers' Association.

The dried peaches are carried on a metal conveyor through a boiling, approximately 20 per cent sodium bicarbonate solution, which loosens the skins. They then pass through a screen cylinder in which revolve stiff-bristled, spiral-shaped brushes. These brushes rub the peaches against the screen and thus remove the loosened peels; and sprays of water wash the peels and adhering soda solution through the screen to the waste drain. This process removes most of the peel from the ripe fruit, but unripe peaches do not peel satisfactorily.

The "practically peeled" fruit next passes by means of a conveyor through a tunnel dryer heated by steam coils. This removes excess surface moisture, which would otherwise cause molding or fermentation in the packages, or would cause the packages, because of drying, after a few weeks' storage to contain a much lower net weight of fruit than is placed in them at the time of packing.

The peaches are spread on trays and sulphured, usually overnight. They are packed in attractively lithographed cartons holding 1, 2 and 5 pounds each.

More than 60 per cent of the dried peaches packed by the Growers' Association are "practically peeled."

PACKING DRIED PEARS

Dried pears, because of the heavy sulphuring given them before drying, and because they are removed from the trays while still pliable, usually require no processing in water or sulphuring before packing.

Grades.—In a large dry yard and packing house in central California the pears are graded for size and quality by women who stand before a slowly moving belt. The grades made in this plant are Jumbo (largest and finest fruit), Extra Fancy, and Northern California pears. The three best grades are packed as Lake County pears. In another packing house the following grades are made: Extra Fancy, Fancy, Extra Choice, Choice and Standard.

Packing.—The sorted fruit is packed in 10-, 25- and 50-pound boxes. Overdried fruit is processed before packing, as described elsewhere for apricots.

PACKING DRIED PRUNES

The processing, grading and packing of prunes is a specialized industry separate and distinct from the growing and drying industry. While the varieties of prunes are different in the two regions, the methods followed in the commercial packing of prunes in the Pacific Northwest and in California are very similar.

Receiving and Door Test.—The prunes are generally allowed to undergo sweating in bins or boxes at the dry yard or dryer before delivery to the packing house.

In most packing houses each load of prunes as delivered is sampled carefully and the number of prunes per pound determined. This is known as the "door test," on the basis of which some packing houses pay the grower.

Grading.—Each lot is size-graded, in most packing houses immediately after delivery, and the weights of prunes falling into the different size grades are determined. A grader similar to that used for peaches for canning and equipped with vibrating screens with circular openings is used for grading. Immediately beneath each screen is a bin; thus prunes of "40 to 50" size fall into one bin, "30 to 40's," etc., into other bins. The graded prunes are transferred to large wheelbarrows or trucks for weighing and are transported to storage bins. The usual size grades and corresponding diameters of screen openings are given in Table 75.

Before entering the grader the prunes pass over a vibrating screen which removes loose dirt, leaves, stems, etc.

Table 75.—Size Grades for Dried Prunes in California

(After Cruess and Christie's "Laboratory Manual of Fruit and Vegetable Products")

Number of prunes per pound	Diameter of grader holes, inches
20 to 30	over $\frac{40}{32}$
30 to 40	$\frac{40}{32}$
40 to 50	$\frac{38}{32}$
50 to 60	$\frac{36}{32}$
60 to 70	$\frac{33}{32}$
70 to 80	$\frac{32}{32}$
80 to 90	$\frac{30}{32}$
90 to 100	$\frac{28}{32}$
100 to 110	$\frac{26}{32}$
110 to 120	$\frac{24}{32}$
120 and up	below $\frac{24}{32}$

Processing.—The processing of dried prunes consists in immersing them in hot water for a period of 2 minutes or more in a processor which consists of a long metal tank filled with water heated to boiling or nearly to boiling by steam coils or open steam jets and of a conveyor equipped with perforated sheet metal buckets.

Processing cleanses the fruit, destroys all insect life and renders the prunes soft, pliable and of glossy appearance. The fruit increases in weight about 6 to 8 per cent through absorption of water.

Packing and Cooling.—The prunes are packed directly from the processor without drying or cooling, 25- and 50-pound boxes lined with paper being the usual containers. The hot fruit is filled into the boxes by weight and pressed flush with the top of the box with a hand lever press or with a continuous dried fruit press.

The boxes retain a high temperature for several hours, if packed closely together, resulting in caramelization of the sugars in the fruit and in severe injury to quality. The boxes are therefore stacked in staggered fashion so that air currents may pass freely between them and cool them quickly.

Cartons holding 3, 5 and 10 pounds of prunes are now used quite extensively. They are of convenient size for the average family and insure that the prunes reach the consumer in good condition.

Canning.—Prunes, to some extent, are packed scalding hot in cans and sealed under a high vacuum. When packed in this manner they preserve their original glossy appearance and soft texture and do not undergo "sugaring." They are also packed hot into cans and exhausted in live steam for 15 minutes before sealing. Unless vacuum sealed or thoroughly exhausted before sealing, corrosion and perforation of the tin plate are very common and spoilage losses from these sources very heavy.

Prunes are also cooked with water or dilute syrup or are canned in dilute syrup in the same manner as fresh plums and other fruits.

Pitted Prunes.—Small prunes, sizes smaller than 100 to the pound, are now used for the preparation of pitted prunes sold to the baking trade in 25-pound boxes. They are excellent for fruit cakes, plum puddings and pies, and can be used in bread as a substitute for raisins.

The prunes are first treated 6 to 7 minutes in boiling water, then spread on trays which are stacked and allowed to stand overnight to permit the prunes to soften, after which they are dried a short time to remove surface moisture in order to prevent sticking of the fruit to the pitting machine. They are pitted by a machine similar to that used for seeding raisins.

Packing Artificially Dried Prunes.—Evaporated prunes in Oregon and California are packed in a manner very similar to that described for California sun-dried prunes. Generally, however, the Oregon prunes are processed in steam rather than in boiling water.

The same size grades prevail in Oregon as in California.

Christie[6] processed six different lots of dehydrated prunes in water and in steam to obtain data on the relative rates of moisture absorption in the two media, as shown in Table 76.

TABLE 76.—RELATIVE RATES OF ABSORPTION OF MOISTURE BY PRUNES PROCESSED IN BOILING WATER AND IN STEAM

(*After Christie*)

Lot No.	Moisture, per cent in original prunes	Percentage of moisture							
		Minimum in hot water			Minimum in steam				
		2	4	6	2	4	6	8	10
1	17.3	.....	.....	.....	20.3	20.7	21.5	22.4	23.3
2	21.4	23.0	24.9	28.6*	....	22.9	....	24.2	
3	21.9	24.1	26.9†	30.7*	22.9	23.3	23.9	24.5	25.9
4	21.6	28.3†	29.5*	31.3*	23.9	25.2	25.6	26.1	27.0†
5	21.5	24.9	26.8†	27.8*	23.0	23.2	24.0	25.0	25.1
6	16.8	21.0	23.0	25.0	18.6	20.0	20.3	21.1	21.5

* Very moldy. † Trace of mold.

The results showed that prunes of a moisture content of 28.6 to 30.7 per cent became moldy and that those of 25 per cent moisture did not mold.

Moisture absorption was more rapid in water than in steam.

PACKING OF RAISINS

The mechanical equipment used in preparing and packing raisins has been brought to a high state of development.

Bulk-packed raisins are handled throughout by machinery; only certain kinds of carton goods and layer raisins are packed by hand.

Receiving.—The raisins are delivered in sweat boxes holding about 175 pounds of raisins each. The raisins are usually sampled and a moisture test made. The packer desires the raisins to contain not more than 16 per cent of moisture, because if the moisture content is excessive it is very difficult to remove the stems.

Stemming.—All varieties of raisins are passed through a stemming machine, consisting of a screen cylinder which revolves close to a half cylinder of the same material. The raisins are given a rubbing motion as they pass between the two screens and the coarse stems are broken from them. The stems in the old-style stemmers are removed by a blast of air, which also removes some of the small and light raisins. In the latest type of stemmer the stems are removed by revolving "combs" which pick up and remove the stems but permit the raisins to pass through to a conveyor which carries them to the grader.

Grading.—Stemmed raisins are graded by means of vibrating screens into the following grades:

A. Loose Muscats (stemmed raisins):

1. One-crown, $^{13}\!/_{32}$ of an inch in diameter.
2. Two-crown, $^{17}\!/_{32}$ of an inch in diameter.
3. Three-crown, $^{21}\!/_{32}$ of an inch in diameter.
4. Four-crown, over $^{21}\!/_{32}$ of an inch in diameter.

B. Seeded Muscats (above sizes seeded).

The seedless raisins are usually graded for size, but the grades are not so clearly defined as for the Muscat raisins. These are classified, according to the method used in drying the fresh grapes, as "natural" (not lye dipped or bleached), "bleached" (sulphured before drying) and "soda dipped" (lye or soda dipped before drying).

Layers are classified according to size of the berries and bunches, as Vineyard Run, Three-crown Layers, Four-crown Clusters and Six-crown or Imperial Clusters. The Three-crown Layers are the smallest and six-crown, or Imperial, the largest in size.

Drying for Cap Stemming.—Many of the stemmed raisins still retain the "cap" stems (the small stems which attach the berries to the main stem). These must be removed before the raisins are seeded or packed. Muscat raisins cannot be cap stemmed satisfactorily unless they are dried to less than 12 per cent of moisture.

In one of the large dryers the raisins are fed mechanically on the topmost woven wire draper of the dryer, which is about 10 feet wide and about 50 feet long and are spread to give a load of about 5 pounds per square foot. The initial temperature on this draper is about 120°F. The draper carries the raisins slowly to the opposite end of the dryer and drops them to the draper immediately below. The raisins traverse the length of the dryer seven times during drying, the temperature increasing as they progress until they reach a temperature of 165 to 180°F.

Heat is furnished by heated air blown upward through the drapers of raisins by a powerful multivane fan.

The raisins are delivered by the lowermost draper to a cooling draper, on which they are chilled by an upward blast of cold air. This hardens them by increasing the viscosity of the invert sugar syrup in the raisins and gives them sufficient rigidity to withstand cap stemming. The drying time is about 5 hours.

Only Muscat, Malaga and other large varieties of raisins require the drying process described above. Thompson Seedless and Sultana varieties can be cap stemmed without such drying.

Cap Stemming.—The cap stemmer consists of two concentric truncated cones made of heavy screen. One cone revolves rapidly and the distance between the cones is such that the raisins are rolled and rubbed vigorously to remove the stems. The cap-stemmed raisins pass over a screen and through a blast of air to separate them from the dislodged cap stems.

Seedless raisins are sprinkled with water as they enter the cap stemmer.

Floating.—The one-crown, *i.e.*, smallest size Muscat raisins are not seeded. They contain as they come from the stemmer many light immature dried berries. These immature and worthless raisins are removed by flotation in water.

Seeding.—The larger sizes of cap-stemmed Muscat raisins are generally seeded. The raisins are first treated in water at about 200°F. and steamed to soften them and to return the moisture removed in drying for cap stemming. The processor consists of a tank of heated water in which revolves a screen cylinder which carries the raisins through the water. The heating loosens the seeds and softens the pulp so that the seeds can be removed readily.

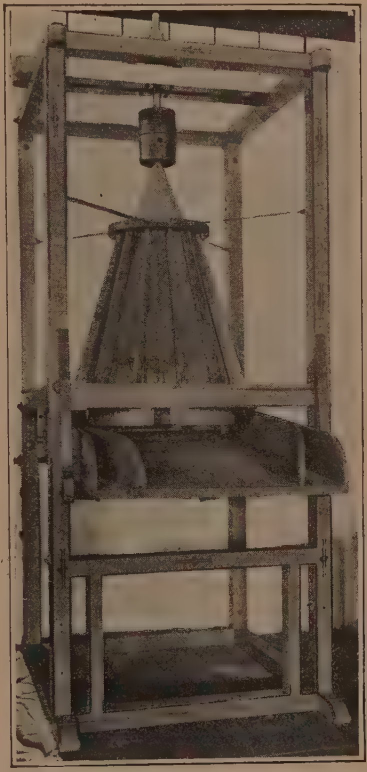

Fig. 92.—A cap stemming machine for raisins, showing conical revolving screen.

The seeder is equipped with four rolls. Two of these are of rubber, one is made up of very fine-toothed circular saws and one of coarse circular saws. The fine saws are known as the "seeder rolls" and the coarse saws as the "flicker rolls." The rubber rolls press the raisins against the revolving fine-toothed circular saws (the seeder rolls). The flesh of the raisins is pressed into the saw teeth. The seeds remain on top of the saws and are removed by the coarse saws. Rubber rolls next force the raisins between metal fingers so adjusted that the soft raisins pass between them and the hard seeds are caught and removed. Fourteen seeders handle the output of ten continuous dryers, or approximately 40 tons of raisins per hour.

Seeding has greatly increased the popularity of Muscat raisins and has made their use in baking, confectionery, ice cream and in general cookery possible.

Packing.—The hot seeded Muscat raisins direct from the seeder are packed by women into 12- and 15-ounce cartons or into boxes holding 25 and 50 pounds. Fiber board cartons are now very generally used as containers for raisins for the baking trade and other users of bulk raisins. These containers are lined with heavy, waxed paper which retards evaporation and thereby reduces the tendency for these raisins to "sugar" during storage.

The Thompson Seedless (Sultanina) raisins and other seedless raisins are packed by automatic machines into small cartons or in bulk boxes. In 1922 about 15,000 tons of the Thompson Seedless raisins were packed and sold in small cartons which retail for 5 cents each.

Other Packages.—Seeded Muscat raisins are also packed in sanitary cans for shipment to the tropics, and in this form are proof against spoilage. The recommended process consists in increasing the moisture content to 30 per cent, canning, exhausting 15 minutes at 200 to 212°F., sealing, sterilizing at 212°F. for 25 minutes and cooling. The 8- and 12-ounce cans are preferred.

Layer raisins are packed very carefully into shallow cartons for dessert use. They are also frequently used in fancy mixed packs of raisins, nuts, figs and peaches for the holiday trade. (See paragraph on "grading" for different grades of layer raisins.)

Fumigation.—Seedless raisins are not heated before packing and hence should be fumigated, preferably in the final insect-proof package.

The seeded Muscat is not so liable to infestation because it is sterilized effectively by heat during drying for cap stemming and again during the seeding process.

PACKING DEHYDRATED VEGETABLES

During the World War it became necessary to develop methods of packing which would protect dehydrated vegetables against insects and moisture.

Effect of Moisture.—Vegetables must be dried to a low moisture content and the package must protect them against absorption of moisture, otherwise the vegetables discolor and rapidly deteriorate in flavor. Their moisture content should be maintained below 8 per cent.

Dehydrated vegetables, according to Nichols,[7] will undergo molding if the moisture content exceeds 20 per cent.

Packages.—Nichols[7] has found that a tightly sealed carton is satisfactory for storage of dried vegetables in an arid climate but unsuitable for use in a moist climate, because under the latter condition moisture penetrates the package readily, even if paraffined, and increases the moisture content of the vegetables to the point where rapid deterioration ensues. Some of the changes are enzymic, others purely chemical.

Friction top cans were found to be reasonably resistant to moisture absorption and relatively inexpensive and convenient. For use of the U. S. Army, the vegetables were sealed by solder in 5-gallon cans. Cans sealed by double-seaming are satisfactory, but more expensive than cartons and less convenient than friction top cans. Vacuum packing has been found to improve the keeping quality of dehydrated vegetables greatly.

Fumigation.—Dried vegetables should always be fumigated or otherwise rendered free of insect life. Those packed in cartons are best fumigated in vacuo. (See paragraphs in this chapter on insect control.)

Sterilization by Heat.—Heating to 145 to 160°F. for 2 or 3 hours will kill the eggs and other forms of insects, and this can be done before or after packing.

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CHAPTER XXIV

VINEGAR MANUFACTURE

The manufacture of vinegar provides a means of utilizing a large proportion of the cull fruit from apple packing establishments and the peels and cores from apple dryers and canneries. Other cull fruits, such as oranges, grapes, prunes, peaches, pears, pineapples, bananas and starchy vegetables, such as sweet potatoes, can also be utilized for vinegar manufacture.

Definitions.—Vinegar may be defined as a condiment made from various sugary and starchy materials by alcoholic and subsequent acetic fermentation.

Cider Vinegar.—The Pure Food and Drug Act of the United States defines cider vinegar or apple vinegar as "the product of alcoholic and subsequent acetous fermentation of the juice of apples." According to the Pure Food and Drug Regulations the word "vinegar" unqualified can be applied only to vinegar made from apples. However, the word "vinegar" is derived from the French *vin aigre* (sour wine).

Cider vinegar is laevorotatory. It contains at least 4 grams of acetic acid per 100 cubic centimeters and at least 1.6 grams of apple solids per 100 cubic centimeters, of which not more than 50 per cent are reducing sugars. It must be stated, however, that most of the cider vinegar on the market need not conform to these standards for the reason that it is diluted with water and the label on the container bears a statement to that effect. Diluted cider vinegar must contain at least 4 grams of acetic acid per 100 cubic centimeters but need not conform to the other standards noted above.

Grape vinegar or wine vinegar is made by the alcoholic and subsequent acetous fermentation of the juice of grapes and must, at 20°C., contain more than 1 gram of grape solids, more than 0.13 grams of grape ash and at least 4 grams of acetic acid per 100 cubic centimeters.

Spirit vinegar, distilled vinegar, grain vinegar, is the product made by the acetous fermentation of dilute distilled alcohol and contains, in 100 cubic centimeters (20°C.) not less than 4 grams of acetic acid.

Miscellaneous Commercial Vinegars.—In a recent decision by a court in the eastern United States, vinegar made from the dried peels and cores may be labeled "Apple vinegar from dried cores and peels" and the names "cider vinegar" and "apple cider vinegar" are reserved for use in labeling vinegar made from the juice of the whole fresh fruit. This question is still a matter of controversy.

Any fruit which contains more than 9 per cent sugar can be converted into a vinegar which will contain more than the legal minimum of 4 grams acetic acid per 100 cubic centimeters.

One of the largest sources of distilled vinegar is the waste liquor from the manufacture of compressed yeast. Starchy vegetables are sometimes used in the manufacture of distilled vinegar. This is particularly true in Germany where potatoes are used for this purpose.

Relation of Fruit Vinegars to Horticulture.—Where vinegar is produced on a large scale commercially, as in the case of apple vinegar, this manufacture acts as a balance wheel for the industry by absorbing much of the fruit which would otherwise appear on the market in competition with graded fruit to the disadvantage of the latter.

Uses of Vinegar.—In addition to its use on the table one of the principal commercial uses of vinegar is in the manufacture of pickles. arge quantities are also used in the manufacture of tomato catsup, chili sauce and sauces used in the canning of fish. It is also used in the manufacture of acetic acid and for the production of acetone, a solvent used in the manufacture of smokeless powders.

Preparation of Fresh Fruits.—Juicy fruits, such as apples, grapes and oranges, are usually crushed and pressed without preliminary fermentation of the crushed fruit before pressing.

Apples are grated and pressed as in the preparation of unfermented cider. The pomace contains a considerable amount of juice, a large proportion of which is recovered by grinding in an apple grater and pressing. A larger yield is obtained by placing the pomace in tanks and permitting it to ferment for 2 or 3 days before pressing. If this method is employed, 10 to 20 gallons of actively fermenting cider per ton of pomace must be added and mixed with the pomace in order to promote yeast fermentation and prevent acetification. If the pomace or other raw material acetifies (becomes vinegar sour) the acetic acid will in may cases stop alcoholic fermentation and result in a partially fermented inferior vinegar. The juice expressed from the pomace should not be mixed with the juice from the whole apples because it is inferior in quality.

Grapes are crushed and pressed as for making white juice.

Cull oranges are used in a large factory in California for vinegar manufacture. The process now in use was developed by Chace and Poore of the Citrus By-products Laboratory of the Bureau of Chemistry, U. S. Department of Agriculture, in Los Angeles, Cal. The juice is expressed with large, fluted, bronze rolls. The fresh juice containing the orange oil from the skins is centrifuged for recovery of the oil and the juice then is used for vinegar making.

Pears, peaches, apricots, fresh prunes, plums, ripe bananas and other pulpy fruits should first be crushed and allowed to undergo alcoholic

fermentation for several days before pressing since preliminary fermentation facilitates pressing and increases the yield.

Dried Fruits.—Dried fruits contain from 50 to 70 per cent sugar. Enough water should be added to reduce the sugar content of the mixture to about 15 per cent and the mixture allowed to ferment until well disintegrated before pressing.

Dried apple peels and cores are used in the eastern United States for the production of vinegar. In the process of evaporation of such material it is treated with the fumes of burning sulphur and therefore contains sulphurous acid. In order that the vinegar made from the peels and cores shall resemble that from fresh apples, the sulphurous acid is removed by treatment of the wash with barium peroxide, which oxidizes the sulphurous acid and precipitates it as barium sulphate. The two following reactions will make this point clearer:

$$\begin{aligned} BaO_2 + H_2SO_3 &= H_2SO_4 + BaO \\ BaO + H_2SO_4 &= BaSO_4 + H_2O \end{aligned}$$

Preparation of Starchy Tubers, Etc.—Starchy vegetables, such as potatoes, must be hydrolyzed with diastase or with dilute mineral acids before fermentation. The crushed vegetables are heated under pressure in a closed retort, or more slowly by boiling in water or by steaming at atmospheric pressure to gelatinize or dissolve the starch. The mixture must then be cooled to 60°C. if it is to be hydrolyzed with malt. Two to five per cent of ground malt should be added, mixed with the gelatinized mass and stirred until the starch is converted to maltose by the following reaction.

$$\underset{\text{Starch}}{(C_6H_{10}O_5)x} + \underset{\text{Water}}{x(H_2O)} = \underset{\text{Maltose}}{x(C_{12}H_{22}O_{11})}$$

This process is known as "mashing" and the vessel in which the process is conducted, the "mash tun." It consists of a large, circular tank equipped with a stirring device and open steam coils.

The progress of hydrolysis is observed by testing with iodine solutions as follows: A drop of the mash is placed in a dish and a drop of dilute iodine solution is added. If starch is still present, a deep blue color is obtained.

Sweet potatoes normally contain 25 to 30 per cent total carbohydrates, of which starch forms the major proportion, and Irish potatoes usually contain from 16 to 22 per cent starch. Sweet potatoes produce a palatable vinegar without distillation, but because of the disagreeable flavor of fermented Irish potatoes, vinegar is made from the alcoholic distillate from the fermented material.

The gelatinized starch may also be converted to fermentable sugar, in this case dextrose, by treatment in retorts under steam pressure with a

dilute mineral acid, such as HCl and, the acid neutralized with Na_2CO_3, $CaCO_3$ or NaOH after hydrolysis.

Theory of Alcoholic Fermentation.—The manufacture of vinegar requires two fermentation processes. The first of these is fermentation of the sugars to alcohol and carbon dioxide, and is accomplished by yeast. The second fermentation results in the oxidation of the alcohol to acetic acid and is caused by vinegar bacteria. The reactions involved are shown by the following equations:

$$C_6H_{12}O_6 = 2CO_2 + 2C_2H_5OH$$
$$2C_2H_5OH + 2O_2 = CH_3CO_2H + 2H_2O$$

An intermediate step in acetification is the formation of acetaldehyde by the following reaction:

$$C_2H_5OH + O = CH_3CH{:}O + H_2O$$

Effect of Acetic Acid on Yeast.—The two fermentations, alcoholic and acetic, cannot take place simultaneously for the reason that the acetic acid formed by the vinegar bacteria retards yeast growth and activity. Experiments made by the writer prove that *Saccharomyces ellipsoideus* ceases growth and fermentation, if the acetic acid concentration exceeds 0.5 per cent. This amount of acid is often formed in the commercial manufacture of vinegar from waste fruits before alcoholic fermentation where unsound material is used and pure yeast is not added. "Stuck" tanks, those in which alcoholic fermentation has ceased before fermentation is complete, are common on this account.

Vinegar bacteria themselves are not necessarily injurious to the growth of yeast; it is only the product of their activity, namely, acetic acid, that is harmful.

Effect of Vinegar Bacteria on Sugar.—Vinegar manufacturers have stated to the writer that sugar remaining in "stuck" fruit juices will be converted by vinegar bacteria into acetic acid without the intervening step of alcoholic fermentation but experiments have proved that such is not the case.

Wild Yeasts.—Various forms of wild yeast are very troublesome in the fermentation of fruit juices. Most of these have been described in Chapter I, but brief reference may be made at this time to their relation to vinegar manufacture.

Hansenia apiculata.—A wild yeast that is present in practically every spontaneous fermentation of fruit juice. It develops very rapidly in the juice and consumes a large proportion of the non-saccharine yeast foods, reducing these substances to such a degree that the true yeast which develops later finds it very difficult to multiply. It is also thought that *apiculatus* excretes substances that are poisonous to the true yeasts. For example, it forms acetic acid which is deleterious to true yeast activity.

It forms very small amounts of alcohol and is very inefficient in its alcoholic fermentation, that is, only a small proportion of the sugar destroyed by this yeast is converted into alcohol. In samples examined by the writer the *apiculatus* yeast outnumbered the true yeast in fresh apple juice, and in many samples the ratio was 1,000,000 of *apiculatus* cells per cubic centimeter to 100 or less of the true yeast, *Saccharomyces ellipsoideus*. It may be controlled in the fermentation of fruit juices by the addition of a large starter of pure yeast in the manner to be described later.

Mycoderma.—Another wild yeast of common occurrence and one which is very objectionable in the preparation of fruit vinegar is *Mycoderma*, commonly known as "wine flowers," or "vinegar flowers," according to whether it occurs on fermented grape juice or fermented cider. There are, however, hundreds of varieties of this organism. It is strongly aerobic and develops on the surface of fermented or fermenting fruit juices or other fermented liquids of alcoholic or sugary nature. Its cultural characteristics have been described in Chapter I. It is characterized by its vigorous oxidation of alcohol, sugars and organic acids to carbon dioxide and water. Where the organism is grown in pure culture in fermented fruit juice it will, in a few months' time, destroy all the alcohol and will convert such a liquid from an acid to an alkaline reaction. Typical oxidizing reactions caused by this organism are the following:

$$12\ O + C_6H_{12}O_6 = 6\ CO_2 + 6H_2O$$
$$C_2H_5OH + 6\ O = 2\ CO_2 + 3H_2O$$

The organism is very common in cider vinegar factories and develops frequently in the spontaneous fermentation of cider. Normally it develops after the yeast fermentation is complete and before the acetic acid fermentation begins, as a chalky-white, wrinkled film which usually possesses more or less of a fruity ester odor. Its development in fermented liquids can be prevented by the addition of vinegar or by excluding air. If the acetic acid is increased to 1 per cent or more *Mycoderma* does not develop rapidly.

Torula.—A third group of wild yeasts of considerable importance in the fermentation of fruit juices is that of the *Torula* yeasts, which are characterized by rapid growth as sediment yeasts, low alcohol-forming power and usually by their spherical appearance under the microscope. They are objectionable in the fermentation of fruit juice for the same reasons as those given for *apiculatus* yeast. Their growth may be checked by the addition of a pure yeast culture.

Other Wild Yeasts.—There are a number of other yeasts which develop in the fermentation of fruit juices, but these need not be described

in detail at this time. A discussion of most of these organisms will be found in Chapter I.

Desirable Yeasts.—In general it may be stated that the most desirable fermentation of fruit juices and other liquids intended for vinegar manufacture is the one carried out by the so-called "culture" yeasts, such as *Saccharomyces ellipsoideus*, *S. malei* and *S. cerevisiae*, from grapes, apples and cereals respectively. These yeasts are characterized by their efficient conversion of sugar to alcohol, by rapid settling after fermentation and by the production of fermented liquids of clean flavor and normal appearance.

As stated above, the desirable types of yeast are greatly outnumbered by various wild yeasts. In order that the injurious effect of these undesirable organisms may be minimized and that a desirable type of fermentation may be obtained, selected cultures of pure yeasts should be added. This addition will reverse the ratio of wild yeasts to true yeasts and will promote the type of fermentation desired. *Saccharomyces ellipsoideus*, most commonly found in grape juice fermentations, because of its rapidity of growth and fermentation and its high alcohol forming power, has been found most satisfactory for fermentation of fruit juices for vinegar manufacture.

For the fermentation of mashes made from starchy materials the yeasts of the *Saccharomyces cerevisiae* group are best.

Commercial Yeast Culture.—Several institutions in the United States distribute cultures of yeasts for vinegar manufacture. Among these may be mentioned the University of California, College of Agriculture, Berkeley, Cal.; the Colorado Experiment Station, Ft. Collins, Colo.; and the Wahl-Henius Baking Institute, Chicago, Ill. The yeast is ordinarily sent to the vinegar manufacturer as a pure culture on nutrient agar-agar in a flask or tube plugged with cotton and with full directions for its increase to sufficient volume for factory use.*

Using the Starter.—It will be found that 50 gallons of actively fermenting liquid will be sufficient for the inoculation of 500 gallons of fresh juice. This amount of juice should be pressed from sound, selected and well-washed fruit and the juice should be placed in a clean tank, preferably one that has been washed thoroughly with a sal soda solution and steamed to render it as nearly sterile as possible. It is then mixed with the 50 gallons of "starter." Within 4 or 5 days the 500 gallons of juice will be actively fermenting and can be used to inoculate about 5,000 gallons of fresh juice. The 5,000-gallon tank of juice can, in turn, be used to inoculate 50,000 gallons of juice. From this point the fermentations in the factory may be started by using 10 per cent by volume

* The student is referred particularly to Bulletin 287 of the University of California Experiment Station.

of actively fermenting juice from a tank previously inoculated by pure yeast starter.

In factories where fruit of an inferior quality is used, that is, fruit which is often fermenting or vinegar-soured when received at the factory, it will be necessary to renew the pure yeast culture frequently during the season; but if fruit of sound quality is used one culture will be sufficient for the normal vinegar making season.

Aeration.—The growth of culture yeasts is increased by aeration and agitation of the fermenting liquid. Aeration mixes the yeast thoroughly with the fermenting liquid. It removes carbon dioxide, which has a retarding influence on fermentation, and furnishes oxygen, which favors the growth of the yeast. In the ordinary vinegar factory, however, sufficient aeration is obtained by the crushing, pressing and pumping of the liquid before fermentation. It has been found advisable to aerate by pumping over tanks of juice that have become sluggish in fermentation and in which there is danger of "sticking," *i.e.*, complete ceasing of fermentation.

Temperature Control.—During the fermentation of any liquid in large tanks the temperature rises because of the heat liberated during the conversion of sugar into alcohol. The alcoholic fermentation of 1 gram of sugar liberates 120 calories and the fermentation of 1 gram of sugar per 100 cubic centimeters of juice would theoretically increase the temperature 1.2°C., or approximately 2.16°F. Yeast fermentation ceases at 105°F., or approximately 40.5°C. Grape juice normally contains about 22 per cent sugar and in the fermentation of this amount of sugar the rise in temperature would be approximately 47.5°F., if no heat were lost by radiation. It has been found in commercial practice, where fermentation vats of 2,000 gallons or greater capacity are used, and a normal summer temperature of 85 to 95°F. during the day prevails, that it will be necessary to cool the fermenting liquid artificially. The usual means of accomplishing cooling of fermenting fruit juices is to pump the liquid through pipes surrounded by jackets of circulating cool water. In some cases metal coils, through which cool water is circulated, are immersed in the fermenting juice.

Artificial cooling of the liquid is seldom necessary in the fermentation of apple juice, because of its low sugar content and because apples are usually crushed during the fall months when the temperature is not sufficiently high to cause "sticking" of fermentation.

High temperatures are not only injurious to yeast fermentation but also are objectionable because they favor the growth of lactic acid and vinegar bacteria. If possible, the temperature of the fermenting liquid or pulp should be maintained between 75 and 95°F. The optimum temperature for most varieties of culture yeasts used in the fermentation of fruit juices is about 85°F.

Sanitation.—The fermentation tanks should be thoroughly cleansed before being filled with fruit juice or other liquid intended for vinegar manufacture. Not only should the tank be well washed, but it should be treated with a solution such as hot sal soda, or sulphur should be burned in the tank to destroy mold spores, vinegar bacteria and other objectionable microorganisms. The tank, however, should be aerated before the juice is added if sulphur is burned in it, because sulphur fumes dissolve in fruit juices and form a dilute solution of sulphurous acid, which retards acetification. Sour press cloths, unclean crushers, pumps, etc., are prolific sources of contamination of fruit juices with undesirable types of organisms. Such equipment should be kept clean and should be thoroughly washed at the end of each day's operations.

Increasing the Temperature.—The alcoholic fermentation occurs in two stages, one known as the preliminary or violent fermentation, during which most of the sugar is converted into alcohol and carbon dioxide and fermentation is so rapid that foreign organisms find it difficult to develop. The secondary fermentation is very much slower than the preliminary fermentation and usually extends over a period of 2 or 3 weeks as compared with a period of 3 to 6 days for the preliminary period (see Fig. 93). During the secondary fermentation there is danger of contamination by vinegar bacteria, "wine flowers," and lactic acid bacteria. Should the secondary fermentation become very sluggish, it may be necessary to aerate the liquid and thus invigorate the yeast. During the cold winter or late fall months it may be necessary to heat the fermentation room artificially in order that fermentation may not be arrested by low temperatures.

Balling Readings.—The progress of fermentation is readily observed by determining the Balling degree of samples of the fermenting liquid taken daily. When fermentation is complete the Balling hydrometer usually registers 0 degrees or less.

Settling and Racking.—Following the secondary fermentation the yeast and fruit pulp settle rapidly to form a compact sediment in the fermentation tank. In most factories the fermentation vats are used for the storage of the liquid during the first 10 days or 2 weeks of fermentation only and the final stages of fermentation are normally completed in large storage tanks often containing from 30,000 to 50,000 gallons each. In the normal fermentation the sugar content in the fruit juice or other liquid is reduced to less than 0.5 per cent sugar in a period of 3 or 4 weeks after the time of crushing. If more sugar than this is present at the end of 4 weeks it is an indication that fermentation has been imperfect for one or more reasons. It is possible that the temperature has been too high or too low or that bacterial fermentation has retarded yeast fermentation or that the liquid contained too much sugar before fermentation. Few yeasts will completely ferment juices of more than 30° Balling.

After the fermentation is completed and the yeast has settled, the fermented liquid should be separated from the yeast sediment as completely as possible since the sediment tends to undergo decomposition, resulting in the formation of undesirable flavors or the development of lactic bacteria which seriously interfere with acetic fermentation.

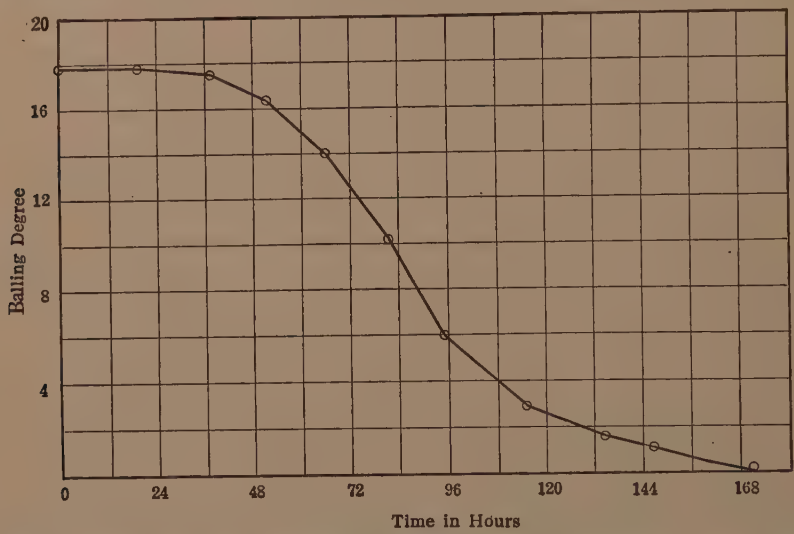

FIG. 93.—Typical pure yeast fermentation curve. Drop in Balling degree plotted against time in hours.

The process of the separation of the liquid from the sediment is known as "racking" and is accomplished by drawing off the liquid by gravity through a faucet, by siphoning or by pumping. The residual sediment is rich in yeast and contains a large amount of liquid suitable for vinegar making which can be recovered by filtering the sediment through filter bags or filter presses, but in most factories the sediment is discarded.

Storage of the Fermented Fruit Juice.—Many vinegar factories store the fermented juices in tanks which are more or less exposed to the atmosphere. This is a mistake, for the reason that it permits the growth of *Mycoderma* or "wine flowers" with a resulting loss of alcohol and injury to the quality of the product. If the juice is to be held for several months, one of three things should be done. The fermented juice should be stored in well-filled closed tanks to exclude air and thereby prevent growth of *Mycoderma*, or, if the juice is stored in open containers it should be acidified by the addition of vinegar to increase the acidity of the liquid to at least 1 per cent acetic acid, or the fermented liquid should be covered with a neutral oil which excludes air, prevents growth of "wine flowers" and reduces evaporation. Crawford* states that the loss from uncovered

* CRAWFORD, S. L., *The Canner*, Dec. 10, 1921, p. 46.

fermented cider in 6 to 12 months may amount to 25 to 50 per cent of the alcohol. He has found the use of a mineral oil covering to be extremely effective in preventing such losses.

Slow Methods of Acetification.—There are two general methods in use for the conversion of alcoholic liquids to vinegar. One of these is the slow process, of which there are several modifications, and the second method is the generator or quick process. The various modifications of the slow process and the generator process will be discussed separately.

The "Let-alone" Slow Process.—In the manufacture of vinegar in the household or in the orchard the juice is usually allowed to undergo spontaneous fermentation in barrels and the barrels are left partially filled with the bung open until the product changes to vinegar of its own accord. The alcoholic fermentation is often incomplete and imperfect. Usually the liquid becomes covered with wine flowers and in most cases acetic acid fermentation is very slow. An abundant supply of air is necessary for the satisfactory acetification of any liquid. This fact is often not realized by the amateur vinegar maker and it is not uncommon to observe completely filled, tightly sealed barrels or other containers set aside to become vinegar, a condition which of course prevents acetification. The "let-alone" process is very unsatisfactory, very slow and often results in the production of a very inferior product.

The "Orleans" process is much more desirable. In this process the fermenting liquid is placed in barrels which are filled about three-quarters full, holes are bored at both ends of the barrel a few inches above the surface of the liquid and the bung hole in the barrel is left open. The holes should be covered with fine screen or with cheesecloth to exclude vinegar flies. To the fermenting liquid is added from one-fourth to one-fifth of its volume of fresh vinegar. This acidifies the liquid to the point where the growth of *Mycoderma* is prevented, and the growth of vinegar bacteria promoted. It also impregnates the liquid with a very large number of active vinegar bacteria and is in the nature of a starter of vinegar bacteria. Usually at the end of 3 months the liquid will be converted into vinegar. One-fourth to one-third of the vinegar may then be drawn off for bottling purposes and an equivalent volume of alcoholic liquid added. From this point forward one-third to one-fourth of the volume may be drawn off at monthly intervals and an equivalent amount of alcoholic liquid added. This process results in aging of the vinegar during acetification and produces a vinegar superior in flavor and general quality to that of the "let-alone" process, or the generator process. It is used extensively in Europe in the preparation of vinegar from wine.

The Pasteur Process.—Pasteur discovered that vinegar bacteria tended to develop on the surface of the liquid with the formation of a translucent film which he believed to be the principal agent in acetification.

He also noted that in the usual Orleans process this film was disturbed during the drawing off of the vinegar and the addition of the new wine or cider and that the tendency of the film was to settle to the bottom of the barrel, where in time the accumulation became so great that it interfered with normal acetification. The submerged film tends to destroy acetic acid. He therefore modified the Orleans process by placing on the surface of the liquid a grating made of thin strips of wood, which retained the film at the surface. By using a shallow tank and thereby increasing the ratio of the surface exposed to the volume of liquid in the tank, he obtained very rapid acetification. The liquid is acetified with one-fourth to one-fifth its volume as described above for the Orleans process.

Observations made by the writer in 1915 indicate, however, that the growth of the film is not a necessary condition. In fact, the most rapid acetification of wine and cider was obtained by the use of cultures which did not form such a film. It is possible that the growth of a heavy leathery film on the surface of the liquid tends to exclude air and actually reduce the rate of acetification.

The Generator or Quick Process.—The rate of acetification is proportional to the amount of oxygen in contact with the reacting components, or, in other words, to the surface exposed to the air, since oxygen of the air is one of the two reacting substances. If the surface, therefore, is increased, the rate of acetification is proportionately increased. This principle is made use of in the quick process, otherwise known as the "generator process" or German process.

Upright Generators.—In this method a tank, usually cylindrical and upright in form, is filled with a substance which will permit the vinegar to percolate freely and upon which vinegar bacteria may develop. The substance most commonly used is beech wood shavings, since they retain their tightly coiled condition even when wet with vinegar and therefore do not pack tightly in the generator. Corn cobs and rattan shavings are also used successfully in generators for the manufacture of fruit vinegar. The rattan shavings are tied to poles to form upright bundles, which are packed tightly in the generator. If not used in this manner, rattan shavings tend to settle into a compact inactive mass. In the manufacture of distilled vinegar, charcoal and coke have been used, although the beech wood shavings are preferred. Coke is more durable than charcoal and is sometimes used in generators in which distilled vinegar is made.

The usual generator is about 48 to 60 inches in diameter, from 10 to 14 feet in height and contains three compartments. A central compartment occupies most of the generator and contains the shavings or other generator material. It is equipped with adjustable openings near the bottom of the generator for admission of air. Angle-stem thermometers are inserted near the center of the compartment.

Above this compartment is a distributing compartment in which is located a tilting W-shaped trough into which the fermented liquid flows in a small stream. The axis of the trough is so placed that when one side has filled with the liquid it tilts and brings the other side of the trough under the stream, which in turn fills and tilts. This tilting action distributes the liquid over the bottom of this compartment which is perforated with small holes through which the liquid flows to the generating compartment below. It trickles slowly over the shavings or other filling material and is oxidized to vinegar during passage. The third compartment is merely a receiving chamber for the acetified liquid. By the slow process, acetification requires from 1 to 24 months according to the temperature and other factors and in the generator process only a few minutes, because of the enormous surface exposed for acetification. The surface of the shavings or other filling material becomes coated within a short time with a heavy growth of vinegar bacteria. The construction of such a generator is shown in Fig. 94.

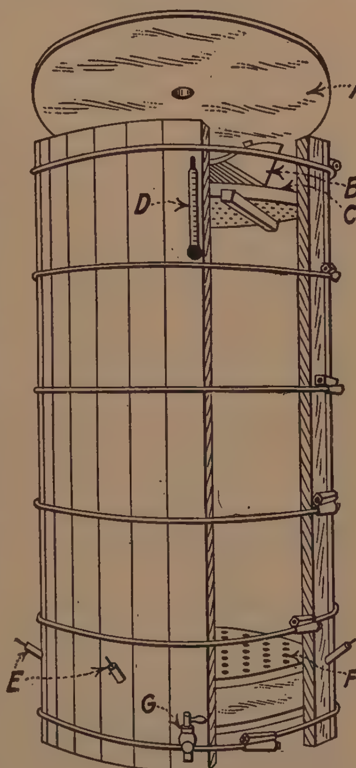

FIG. 94.—Upright vinegar generator. *A*, cover; *B*, distributing trough; *C*, distributing head; *D*, thermometer; *E*, air inlets; *F*, false bottom. (*Courtesy, the Hydraulic Press Mfg. Co.*)

Use of Upright Generator.—In order to start the generator it is first necessary to acidify the shavings or other filling material, which may be done by filling the generator with new cider vinegar or other fruit vinegar. This vinegar will not only acetify the filling material but will also impregnate it with active vinegar bacteria. Following acidification of the shavings a fermented liquid acidified with vinegar should be slowly passed through the generator in order to stimulate growth of the vinegar bacteria. Within a few days the growth of the bacteria will have proceeded sufficiently to permit normal operation of the generator.

In the usual "one-run process" the alcoholic liquid is acidified by the addition of vinegar to increase the acidity to 3 to 3½ per cent, representing about 1 gallon of hard cider to 2 gallons of vinegar. One passage of this liquid through the generator will convert the remaining alcohol to acetic acid. In the case of cider this will mean an increase of acidity from 3 or 3½ per cent to about 6 per cent.

In the "two-run process" the freshly fermented liquid is passed through the generator to become partially acidified and this liquid is then passed through a second generator to complete the process. There is more danger of undesirable bacterial growth and inefficient operation of the generator by the two-run process than by the one-run process, for the reason that the high acidity in the latter process checks the growth of undesirable organisms and promotes the growth of vinegar bacteria.

In California an upright generator will convert 15 to 30 gallons of alcoholic liquid into vinegar per 24 hours, that is, the conversion of a mixture of 30 to 60 gallons of vinegar and 15 to 30 gallons of alcoholic liquid to vinegar. The operation of the generator must be carefully controlled by frequent determinations of alcohol and acid of the ingoing and outgoing liquids.

Revolving Generators.—In commercial installations using this principle, a large cylinder filled with shavings revolves within a tightly constructed wooden housing. The lower half of the cylinder is immersed in the liquid to be acetified, while the upper half is exposed to the air. The exposed surface remains wet owing to rotation of the cylinder. Air is admitted to the compartment through adjustable openings. The generator revolves very slowly, at the rate of about 1½ revolutions per hour in the plant observed by the writer. The generators in question in this particular case held approximately 500 gallons each of fermented cider and approximately 3 weeks were required for complete conversion to vinegar. The revolving generator has not proved as popular as the upright type, probably because of its cost of construction and operation and greater complexity.

Control of Temperature during Acetification.—In the slow or Orleans process the barrels of vinegar should be kept in a warm room so that the temperature in the container will be favorable for the activity of vinegar bacteria. The optimum temperature for their growth is about 85°F. In the generator process, because of the great rapidity of the oxidizing reaction, the temperature tends to rise because of the heat liberated. One gram molecule of alcohol during its conversion to acetic acid will liberate 115 calories of heat, which is several times the amount of heat liberated during the fermentation of 1 gram molecule of sugar to alcohol, in which case 22 calories of heat are liberated. This corresponds to 2.5 calories, or 2,500 calories per gram of alcohol, converted to acetic acid; or enough heat is liberated by the oxidation of 1 gram of alcohol to acetic acid to raise the temperature of 100 cubic centimeters of water 25°C. (45°F.), if no heat were lost by radiation. Usually, therefore, in the generator process the problem is one of maintaining the temperature below the danger point of 40°C. (105°F.), the temperature at which acetic acid bacteria are inactivated.

Temperature is controlled in a vinegar generator by two means: by adjustment of air intake and by rate of flow of liquid. If the temperature has become too low it may be increased by increasing the flow of liquid and by admitting a larger volume of air through the air intakes at the bottom of the generator. This will result in the oxidation of a larger amount of alcohol per unit of time and in an increase of temperature. On the other hand, if the temperature rises above the optimum of 85°F., the rate of flow of the liquid must be decreased and the air intake reduced. During the warm summer months the temperature of the generators must be carefully regulated, to prevent excessively high temperatures. The output of generators during the winter months will be greater than during the summer months for the reason stated above, other things being equal.

Losses during Acetification.—In the operation of generators appreciable amounts of alcohol and acetic acid are lost by evaporation, by oxidation to carbon dioxide and water and by being utilized by the vinegar bacteria for their growth. Small amounts of alcohol also remain unconverted in the finished product. Theoretically 1 gram of alcohol should yield 1.304 grams of acetic acid. In practice 1 cubic centimeter (0.7938 gram) of alcohol normally yields about 1 gram of acetic acid instead of the theoretical 1.035 grams, and 1 gram of alcohol yields only 1.26 grams of acetic acid. In improperly regulated generators, where the supply of air passing through the generator is too great, the yield may be much less than this. In extreme cases it is possible for all of the alcohol entering the generator to be converted into carbon dioxide and water with the formation of practically no acetic acid. The reaction involved in this case is $C_2H_5OH + 3O_2 = 2CO_2 + 3H_2O$. It is very essential, therefore, that the proper balance between air intake and flow of alcoholic liquid be maintained.

Aging of Vinegar.—Freshly made vinegar, especially that prepared by the generator process, is very harsh in flavor and odor. It has been claimed that this flavor is due to the presence of higher alcohols and acids. If new vinegar is placed in well-filled tanks or barrels and allowed to stand for 6 months or a year, the harsh flavor disappears and is replaced by a mild agreeable flavor and pleasing "bouquet" or odor. The changes that occur during this period are probably similar to those that occur in the aging of wine. The combination of ethyl alcohol and acetic acid, according to the following reaction, to form ethyl acetate, is an example of the reactions that probably occur during aging.

$$\underset{\text{ethyl alcohol}}{C_2H_5OH} + \underset{\text{acetic acid}}{CH_3CO_2H} = \underset{\text{ethyl acetate}}{CH_3CO_2C_2H_5} + \underset{\text{water}}{H_2O}$$

In the slow process of vinegar manufacture, aging and acetification occur simultaneously and therefore such vinegar is ready for use when

acetification is complete. Vinegars from generators, on the other hand, should not be used until they have been aged for at least 6 months. Aging should take place in well-filled wooden containers, as it has been found that it does not occur satisfactorily in glass. The reason offered for the superiority of wood over glass is that wood permits the slow oxidation of the vinegar by the air which enters through the pores of the wood. Aging takes place more rapidly and satisfactorily in small cooperage than in very large tanks.

The Clearing of Vinegar.—Vinegar to be attractive should be brilliantly clear, which condition may be accomplished either by filtration or fining.

Isinglass.—The most satisfactory fining material for vinegar is fish glue of highest quality, otherwise known as fish isinglass or ichthyocoll. This material is made from the sturgeon and is usually imported from Russia. The amount used is ordinarily from 1 to 2 ounces per 100 gallons of vinegar.

It is desirable to make a preliminary clarifying test with small bottles of vinegar with a standard 1 per cent solution of the isinglass in order to determine the amount necessary for the larger amount of vinegar.

The isinglass is dissolved by soaking in water acidified with citric acid equal in weight to the amount of isinglass used. An ounce of isinglass may be dissolved in half a gallon of water by soaking for 24 hours in the acidified water and by rubbing the soaked isinglass through a fine screen. To clarify the vinegar the solution is added to 50-gallon barrels and thoroughly mixed by stirring. The barrels are closed, the liquid allowed to settle for a week or 10 days and the clarified vinegar separated from the sediment by siphoning.

Filtration.—In large factories vinegar is clarified by filtration. The filter in most common use is the pulp filter of which the Karl Kiefer filter is a good example. The brilliancy of vinegar is improved if a small amount of infusorial earth, such as "Filter Cel," is added before filtration.

The metallic parts of the filter which come in contact with the vinegar should be silver plated in order to prevent corrosion. Tin may be used but is in time dissolved by the vinegar and the surface must be retinned occasionally. If iron is in contact with the vinegar it dissolves and reacts with the tannin to form an undesirable blue or black color. Most other metals are soluble and injure the flavor of the product. For this reason vinegar is conveyed throughout the plant by means of wooden pipes or rubber hose and by pumps which are made of porcelain, hard rubber, or other non-corrodable material.

An ordinary filter press may also be used in the filtration of vinegar, provided the filter parts are protected by silver plating or filter presses made of hard rubber or wood are used.

Hard Rubber Equipment.—Pumps, pipe lines, filters and other equipment made of hard rubber are now available and because of the inert nature of the rubber are very desirable.

Pasteurizing Vinegar.—After filtration, vinegar sometimes becomes cloudy because of the growth of vinegar bacteria. This may be prevented by heating the filtered or clarified vinegar to 140°F. for a few seconds. The pasteurization of vinegar in bulk is accomplished by heating it in a continuous stream in a steam-jacketed block tin or aluminum pipe to the pasteurizing temperature and cooling it at once in a water-cooled coil. Bottled vinegar may be pasteurized by immersing the filled bottles in tanks of water and heating the contents of the bottles to 140°F., as described in Chapter XV.

Containers for Vinegar.—Vinegar is marketed in barrels and in bottles. Formerly oak barrels were commonly used for bulk vinegar, but at the present time spruce is used extensively, the interior of the barrels being heavily coated with paraffin. Barrels for shipment of bulk vinegar should, of course, be thoroughly cleansed before use and should be free of any moldy or other disagreeable flavor or odor.

The best grades of vinegar are most profitably marketed in glass containers. Vinegar in bottles should be brilliantly clear, well aged and of pleasing flavor and odor. The bottles are, at the present time, sealed with the ordinary crown cap of the type described elsewhere for fruit juices. The inner cork seal of such caps must be of the best material so that the acetic acid may not penetrate to the metal. Bottled vinegar should be pasteurized in order that it will not become cloudy through the growth of vinegar bacteria.

Vinegar Eels.—One of the most common diseases of vinegar is that caused by the growth of the vinegar eel, *Anguillula aceti.* This organism is about 1/16 of an inch in length and is very slender. It can be seen in vinegar contaminated with it by holding a small sample to the light in a tumbler or test tube, but it is more readily observed with a hand lens. It often occurs in vinegar generators, but may also be present in the alcoholic liquid before acetification takes place. It is believed that it is distributed by spoiled fruit and by vinegar flies. Generators may become so badly contaminated with the eels that acetification is interfered with. In such cases it becomes necessary to remove the filling of the generator, to sterilize it with live steam and to sterilize the shavings or other generator material with steam or boiling water. Hard cider or other liquid contaminated with the eel should be pasteurized and filtered. Tests indicate that the eel can be destroyed by a temperature of 130°F. The organism is strongly aerobic and therefore does not develop rapidly in bottled vinegar.

Slimy Generators.—Vinegar generators sometimes become slimy, which condition is usually caused by operating the generator too long

without cleaning the filling material. Organisms may develop under these conditions which convert the alcohol in the liquid to CO_2 and H_2O and thereby greatly reduce the strength of the vinegar. The cure and prevention consist in thoroughly cleansing the generator and its contents occasionally and in operating the generator carefully, maintaining the proper balance between air supply and flow of liquid. It is usually necessary to clean the shavings near the top of the generator frequently.

Wine Flowers.—"Wine flowers," as noted elsewhere, may become a serious disease of fermented fruit juice and are very prevalent in cider vinegar factories. Storage of the fermented juice in well-filled sealed containers or the acidification of the fermented liquid by the addition of vinegar are the two most effective means of controlling the growth of wine flowers (*Mycoderma*). Air can be most effectively excluded from the stored fermented cider by a covering of neutral mineral oil.

Tourne Bacteria.—In the small-scale manufacture of vinegar from fruit juices the fermented liquids will often be found to be teeming with lactic acid bacteria, commonly rod-shaped and non-motile and about 6 to 10μ in length and about $\frac{1}{2}\mu$ in width. These organisms often produce a disagreeable mousey flavor and odor, cause cloudiness and interfere with acetification. The bacteria are anaerobic and develop very frequently in symbiosis with *Mycoderma vini*. Their growth is reduced by the use of pure cultures of yeast and is favored by the presence of residual sugar in the fermented liquid. Filtration and pasteurization of the fermented alcoholic liquid may be used to eliminate this organism in cases where it has become a serious disease. (See Fig. 3 for appearance of *Tourne* bacteria.)

Vinegar Flies.—The vinegar fly, *Drosophila cellaris*, a very small fly which propagates in piles of fermenting pomace or in rotten fruit or in crevices around the generators, is an almost universal pest in vinegar factories. Its numbers can be reduced by strict observance of sanitary conditions in and around the plant and by disposal of the pomace in such a manner that the flies cannot find a suitable breeding place. Screening of the outlets and tops of the generators and of the doors of the generator room will make conditions in the generator room unfavorable to its existence. The fly does not affect the quality of the vinegar but is an obnoxious pest to the workmen and probably carries vinegar eels from tank to tank in the storage room.

The Vinegar Louse.—This is a very small form of aphid which develops in and around generators under certain conditions. It rarely, however, becomes a serious pest.

Analysis of Vinegar and Fermented Juices.—Determination of acidity, alcohol and extract is essential in the modern vinegar plant. The manufacturer should know the acid and alcohol content of the liquid entering the generators and of the vinegar issuing from them in order

that improper functioning of the generators may be quickly detected. Pure Food Law standards must be met and the manufacturer must be certain that his product conforms in composition to such regulations. Methods of determining the more important constituents are given in Cruess and Christie's "Laboratory Manual of Fruit and Vegetable Products."

Application of Results of Vinegar Analysis.—To be of greatest value to the vinegar manufacturer the results of analysis must be properly interpreted.

Total Acid.—The federal Pure Food and Drug Act requires that vinegar contain at least 4 per cent acetic acid. Most state pure food laws are identical with the federal law in this respect.

In distilled vinegar total acid and volatile acid are practically identical, but in fruit vinegars an appreciable proportion of the total acidity represents fixed organic acids, such as malic, citric and tartaric acids. For a given fruit vinegar, however, the fixed acidity is a fairly constant quantity and if this correction factor is applied the volatile acidity can be determined with reasonable accuracy from the total acidity. In most cases a vinegar is considered to fulfil the legal requirement in regard to acidity if it contains 4 per cent total acids calculated as acetic acid. Four per cent total acids as acetic is equivalent to "40 grams" by the Leo acid tester.

Generators are sensitive to changes in the composition of the "wash" entering them and after the proper proportions of vinegar and alcoholic liquid for the "wash" have been determined, this ratio should be maintained constant. Total acid determinations of the two components and of the blend of "wash" are therefore essential.

Alcohol.—Balling tests of the unfermented juice and alcohol determinations upon the fermented juice are necessary in determining the efficiency of yeast fermentation.

Alcohol determinations must be made upon the "wash" entering the generators and of the vinegar emerging from them in order to insure that the conversion of alcohol to acetic acid is efficient and that the vinegar does not contain too large an amount of unconverted alcohol. Generator vinegar should contain less than 5 per cent of alcohol and 1 per cent of alcohol by volume should yield at least 1 per cent of acetic acid.

Sugar.—A good vinegar should contain less than 0.5 per cent of sugars. A higher percentage indicates incomplete fermentation, usually caused by the presence of an excessive amount of acetic acid during yeast fermentation.

Blending.—The results of analyses are very valuable in the blending of vinegar to maintain a product of uniform composition. Blending is usually necessary because of the variation in composition

of the raw material and in acetification. In most cases total acid forms the principal basis for blending.

Various blending formulas may be employed but the following formula is simple and easily applied.

Let c = per cent acid desired.
a = per cent acid in vinegar of higher acidity.
b = per cent acid in vinegar of lower acidity.
a' = gallons of vinegar a in blend.
b' = gallons of vinegar b in blend.

Then:

$$c - b = a'$$
$$a - c = b'$$

Example.— a = 6 per cent total acid
b = 3 per cent total acid

required proportion of each to give a blend, $c = 4$ per cent.

$4 - 3 = 1$ gallon of vinegar a (6 per cent)
$6 - 4 = 2$ gallons of vinegar b (3 per cent)

This formula may be applied also to the diluting of vinegar with water but in this case b becomes 0.

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CHAPTER XXV

PICKLES

The manufacture of pickles, relishes and condiments is one of the most important of the food industries. Although the preservation of vegetables and fruits in pickled form began as a household art, at present most of the world's supply of pickles is produced in commercial plants.

Types of Pickles.—The cucumber, one of the most important raw materials used for pickles, is packed in many forms; *e.g.*, in plain or spiced vinegar in jars, kegs or cans, or fermented in spiced brine as dill pickles, or packed in mustard, or in chopped form in various relishes. Green tomatoes, peppers, cauliflower and onions are common ingredients of mixed pickles, chow chow, etc.

Sauerkraut is an extremely important pickled product. Recent advertising of the healthfulness of its juice has greatly increased the demand for "kraut."

The olive is the most important fruit used in pickled form. The pickling of ripe olives is described in Chapter XII. Various fruits, but more particularly peaches, figs and pears, are used in important quantities for sweet spiced pickles.

CUCUMBER PICKLES

The cucumber, according to Le Fevre,[1] is one of the oldest of the garden vegetables, originating in the Far East at least 3,000 years ago. Although of semi-tropical origin, it can be grown successfully in practically any locality, provided care is taken to avoid exposure to frost.

The processes of preparing and pickling cucumbers apply in some respects to other vegetables, and for this reason cucumber pickling will be presented first.

Varieties.—Cucumbers for pickling purposes should be of varieties that are firm, of regular form and of good keeping quality. Very large cucumbers are not so desirable for pickling as the smaller sizes.

Le Fevre[1] recommends the Chicago Pickling, Boston Pickling and Shaw's Perfection as among the best varieties for pickling.

Harvesting.—In harvesting cucumbers for pickling great care should be taken to avoid bruising and it is customary to leave ¼ to ⅛ inch of the stem attached.

Cucumbers for pickling should be slightly under-ripe rather than fully mature.

The cucumbers deteriorate rapidly after picking and should be delivered to the factory or salting station as promptly as possible. The time between harvesting to brining should not exceed 6 to 8 hours.

Salting and Fermentation.—Cucumbers must undergo a preliminary fermentation in brine before they are placed in vinegar. A number of different types of bacteria and yeasts are present during fermentation, but the predominant and desirable organisms are lactic acid bacteria

The fermentation and salt curing of the cucumbers are conducted in circular wooden vats from 8 to 14 feet in diameter and 6 to 8 feet in depth and so placed as to extend about 3 feet above the floor of the vat room.

Brine to a depth of about 1 foot is placed in the bottom of the vat to prevent bruising of the cucumbers as the vat is filled. After the vat is filled, brine is added to cover the cucumbers. A circular wooden head is then placed in the vat over the cucumbers and is held in place by 4 by 4 in. cross-pieces secured at the ends by iron clamps. The cover is necessary to keep the cucumbers submerged in the brine, particularly during fermentation.

The concentration of the brine placed on the cucumbers is generally "40° salometer," *i.e.*, approximately 10 per cent salt. Since cucumbers contain more than 90 per cent water, the brine rapidly decreases in concentration during fermentation and storage. A minimum concentration of 8 per cent salt should be maintained during fermentation, to prevent the growth of putrefactive organisms. On the other hand, if the concentration exceeds 10 per cent salt the activity of the lactic acid organisms is greatly retarded. During the first week of fermentation it is customary to add salt to the vat each day, draw off the brine from the bottom of the vat and pump it over the top until the brine is of uniform concentration throughout the vat.

Le Fevre has found that the addition of about 1 per cent of sugar (preferably dextrose) to the brine greatly improves the character of the fermentation because some cucumbers are deficient in sugar and are liable to develop undesirable types of bacteria unless a small amount of sugar is added to the brine.

The fermentation and curing process normally requires from 4 to 6 weeks, during which period the brine is maintained at about 10 per cent salt (40° salometer). When fermentation is complete the salt concentration of the brine is gradually increased and maintained at about 15 per cent salt (60° salometer).

During fermentation and curing the cucumbers change in color from a bright green to an olive green or yellowish-green color and the flesh of a completely cured cucumber becomes translucent and no longer chalky-white and opaque.

Per Cent Salt and Salometer Degree.—Brines are usually tested by a hydrometer known as a "salometer" or "salinometer." Salometer

degree is approximately equal to per cent salt multiplied by 4, as shown in Table 77, compiled by Le Fevre.[1] Baumé degree is also frequently used. It is approximately equal to per cent salt.

Table 77.—Per Cent Salt and Salometer Degree of Brines

(*After Le Fevre*)

Per cent salt in brine	Salometer degree	Per cent salt in brine	Salometer degree
1.06	4	7.42	28
2.12	8	8.48	32
3.18	12	9.54	36
4.24	16	10.60	40
5.30	20	15.90	60
6.36	24	21.20	80
		26.50	100

Changes in Composition during Fermentation.—Cucumbers, according to Le Fevre,[1] contain from 0.5 to 2.5 per cent sugar and during fermentation nearly all of this sugar disappears. Much of it is converted into lactic acid and the remainder, for the most part, is fermented to CO_2 and other gases. Small amounts of acetic acid, butyric acid and alcohol are also formed. The final concentration of lactic acid is about 0.7 per cent.

Cucumbers are very permeable to brine and rapidly absorb salt during fermentation. According to Campbell[8] they absorb 6 to 8 per cent salt during the first 36 hours and at the end of 3 weeks contain about 10 per cent salt.

Storage.—After fermentation is complete the salt concentration of the brine is increased to about 15 per cent, 60° salometer, and if properly cared for, the cucumbers may be held indefinitely in this brine.

A heavy, wrinkled film of yeast (*Mycoderma*) develops on the surface of the brine during storage and must be skimmed off the vats frequently, for the reason that it reduces the acidity of the brine by oxidation and renders the pickles liable to spoilage by putrefactive organisms. Covering the surface of the vats with a neutral mineral oil will prevent the growth of the *Mycoderma.*

Softening.—Softening of cucumbers during fermentation or storage, which sometimes occurs, is usually an indication of use of a too weak brine. Le Fevre[2] has found that the concentration of the brine should not fall below 8 per cent salt, in order to inhibit the growth of *Bacillus vulgatus*, the organism found in his investigations to be chiefly responsible for softening.

Cucumbers badly affected with mosaic disease are very apt to soften during fermentation.

If the *mycoderma* film is allowed to develop undisturbed it will eventually destroy the lactic acid of the brine and induce softening and destruction of the cucumbers by putrefactive organisms.

Sorting and Grading.—The cured cucumbers are known as "salt stock." They are very salty to the taste, firm in texture and possess a pleasing fermented flavor. Before being placed in vinegar they must be sorted, graded for size and processed.

Sorting is done by women as the cucumbers pass before them on a broad belt.

The size grading is generally done by a revolving cylinder with holes of various sizes or by vibrating screens. Some picklers grade the cucumbers for size by hand, claiming that mechanical graders do not give very uniform size grades on account of the irregular shape of the cucumbers.

Size Grades.—The size grades and size designations vary somewhat in different plants, although certain terms such as Gherkins, Midgets, etc , are in common use. Cucumbers 1¼ to 2 inches long are usually termed Midgets. These may be divided into three further size grades, designated Number One, Number Two and Number Three Midgets, averaging about 650, 450 and 340 per gallon respectively. Gherkins are usually 2 to 2¾ inches long and may be classed as Number One, Two and Three Gherkins, averaging approximately 260, 225 and 160 per gallon respectively. Cucumbers for sweet pickles and for fancy keg stock are 2¾ to 3½ inches long. According to Le Fevre[1] the Medium grade cucumbers are 3 to 4 inches long, and according to Shinkle[6] 3½ to 4 inches long. The Large size is 4 inches or more in length. Le Fevre[1] gives the Medium grade as 40 to 120 per gallon and Large as 12 to 40 per gallon.

The pickler generally speaks of size grades for cucumbers in terms of the number per 45-gallon keg, *e.g.*, Midgets, approximately 15,000 to 30,000, Gherkins, approximately 7,500 to 12,000, Medium, approximately 3,600 to 1,800, and Large, 1,000 or less per 45-gallon keg.

Very large pickles are generally sliced or chopped and used for mixed pickles, relishes, etc.

The National Picklers' Association has recently adopted quality standards for cucumber pickles and salt stock.

Processing.—The excess salt is removed from the cucumbers before they are placed in vinegar or sweet liquor by heating them in water in steam heated vats to 120 to 130°F. for about 12 hours. Large sizes sometimes require two such treatments.

If salting, fermentation and storage have been properly conducted the pickles will be firm and crisp but picklers often add alum to the water in the processing vat to harden the cucumbers. Approximately ½ of

1 per cent of alum is used, *i.e.*, about 1 pound per 25 gallons of water. Most states and the federal government permit the use of alum in processing of cucumbers, but require that a statement to this effect appear on the label.

At one time a small amount of a copper salt was added to the water used in processing in order to impart a green color to the pickles, but this practice is now prohibited by the Pure Food and Drug Regulations.

Turmeric or other permissible food color may be added, if desired, provided its use is declared on the label.

Sour Pickles.—Distilled vinegar is used almost to the exclusion of other vinegars for pickles, because of its uniform composition, neutral flavor, light color and low cost.

The cucumbers are often first placed for a few days in a weak vinegar, *e.g.*, "20 to 30 grains" strength (2 to 3 per cent acidity as acetic). This is then removed and replaced with the final vinegar of 30 to 55 grains strength. A vinegar of "40 grains" acidity (4 per cent acetic acid) is generally sufficiently sour. If the vinegar is too low in acid the pickles are apt to spoil.

In one California factory the cucumbers are placed in a 50- to 55-grain (5 to 5.5 per cent acetic acid) distilled vinegar directly after processing and sorting. The water and juice of the cucumbers dilute the acidity of the vinegar and the pickles absorb the vinegar. At equilibrium the average acidity of the pickles and the vinegar is 20 to 30 grains (2 to 3 per cent acetic acid).

Fancy bottle or small keg pack pickles usually receive a weaker vinegar than bulk pickles in barrels.

Sweet Cucumber Pickles.—The cucumbers are prepared as for sour pickles but in order to prevent shriveling by the osmotic action of the sweet vinegar, the processed cucumbers are first stored in plain vinegar of about 5 per cent acidity for a few days and are then placed in a spiced, sweet vinegar.

Many formulas for the preparation of the spiced, sweet vinegar are in use. One used successfully by the writer consists of 4 gallons of water, 4 gallons of distilled vinegar of 8 per cent acetic acid, 20 pounds of sugar (10 pounds brown sugar and 10 pounds refined white sugar) and 1 ounce each of whole cloves, coriander, mustard seed, broken ginger root and mace. The spices are heated in a bag in the liquid to 175 to 200°F. for about 1 hour in a covered vessel. Any loss in volume is replaced by adding water after extraction of the spices. The spices are removed and discarded and the sugar is dissolved in the hot spiced liquid. The vinegar should test approximately 25° Balling at 60°F. and contain 3.5 per cent total acid calculated as acetic acid.

Some manufacturers add sufficient sugar to the vinegar to give a sweet liquor of approximately 40° Balling. Very often alum is added,

but this should not be necessary and if used must be declared on the label.

If sweet vinegars above 40° Balling are used, the pickles should be stored for about a week in a sweetened vinegar of 25 to 40° Balling to prevent shriveling.

Usually cucumbers are mixed with other vegetables in the preparation of sweet pickles; onions, green tomatoes and cauliflower generally being used for this purpose. Whole spices are also frequently mixed with the pickles in the final package.

Dill Pickles.—Dill pickles are prepared by fermentation in a dilute brine flavored with dill herb and spices and are marketed in this brine rather than in vinegar. A weaker brine is used than for the fermentation of cucumbers for vinegar pickles because it permits rapid fermentation.

Spicing and Barreling.—During fermentation 50-gallon barrels are used as containers for the cucumbers. In filling the barrel the head is removed and a layer of dill herb 2 to 3 inches in depth is placed in the bottom of the barrel; cucumbers are then added to fill the barrel about one-half full and mixed dill spices are added. A layer of dill herb is then placed on the cucumbers and the barrel is filled to within 2 or 3 inches of the top. Dill spices are added and a layer of dill herb placed on the cucumbers. A total of 6 to 8 pounds of green or salted dill herb or 3 to 4 pounds of the dry plant is used. If the brined herb is used the brine should also be added to the cucumbers.

A total of about 1 quart of mixed dill spices is used per 50-gallon barrel of pickles. This mixture consists of approximately equal weights of whole cloves, coriander and black pepper and about 1 pound of dry bay leaves per 15 pounds of the mixed whole spices.

Fermenting.—The filled barrel is headed up and the hoops are driven to make the barrel watertight, and through a hole in the head of the barrel a 20° brine (5 per cent salt) is added to fill the barrel to overflowing. The brine should be acidified with about 3 quarts of 4 per cent vinegar per 10 gallons of brine in order to stimulate the growth of desirable organisms. The barrel is stored in a warm room and fermentation allowed to proceed. A temperature of about 80°F. is best since at lower temperatures fermentation is slow and at higher temperatures spoilage or the formation of hollow pickles may occur. The brine hole is left open during violent fermentation, but once or twice a week the hole should be closed for a few minutes with a bung and the barrel rolled to mix the contents. As fermentation proceeds some liquid is lost by frothing and fresh 20° brine must be added to keep the barrel well filled.

Storage.—When fermentation is complete (after cessation of gas formation) the barrel is completely filled with 20° brine and the hole is closed with a bung. The pickles should be ready for use within 6 weeks after beginning of the fermentation.

If the pickles are to be held in bulk for several months it is advisable to increase the salt concentration of the brine to 30° salometer (7½ per cent salt). The pickles are also preserved by canning and sterilizing as described below.

Canning and Bottling.—Cucumber pickles of all kinds and mixed pickles are now successfully canned in heavily lacquered cans.

In one California factory the cucumbers are packed into the cans carefully by hand; brine, vinegar or spiced sweet vinegar, as the case may require, is added. The cans are given a very thorough exhaust at 200°F. (about 8 to 10 minutes), are then sealed and no further sterilization is given. Good results are also obtained if after exhausting and sealing, the sealed cans are processed for about 10 minutes in water at 185 to 200°F.

Pickles packed in glass are usually not sterilized. The pickles are packed into the jars by hand, according to a definite pattern. The packed jars are filled with vinegar or sweet spiced vinegar and sealed.

OTHER VINEGAR PICKLES AND RELISHES

Many kinds of fruit and vegetable pickles are produced commercially.

Onions.—Small onions are first trimmed and peeled. They are generally stored in several changes of water for 3 or 4 days and are then, in some plants, placed in brine strong enough to prevent fermentation, *i.e.*, about 60° (15 per cent salt) and stored until they have become translucent or until used for pickles. The brine is strengthened by addition of salt as required. The salt is leached from the onions with warm water before they are placed in vinegar. Onions are also prepared for pickling by fermentation in brine, of 10 per cent salt (40° salometer), as described earlier in this chapter for cucumbers.

Green Tomatoes and Mango Peppers.—These are usually handled in the same manner as cucumbers.

Cauliflower.—Cauliflower in some factories is placed at once in a strong brine, 60° salometer, and fermentation prevented by maintaining the brine at this concentration until the cauliflower is cured, but Le Fevre[1] recommends that cauliflower be cured in a 10 per cent brine (40° salometer) and prepared for the vinegar in the same manner as cucumbers.

String Beans.—These are usually cured in barrels after mixing with about 60 pounds of salt per 50-gallon barrel. The salt withdraws juice from the beans to give a strong brine. The beans may also be cured by fermentation in brine in the same manner as cucumbers.

Small Peppers.—Small peppers for tabasco sauce, etc., are fermented in wood in brine of about the same concentration as that used for cucumbers.

Processing and Addition of Vinegar.—These various vegetables after curing in brine are prepared and stored in vinegar in much the same manner as described elsewhere for cucumber pickles.

Sweet Fruit Pickles.—Peaches, pears, figs, watermelon rind and grapes are often prepared as sweet pickles. We have found the following method satisfactory. The fruit is cooked in water or in dilute syrup until tender and is then boiled a short time in a syrup of sugar 24 pounds, water 2 gallons, vinegar 1 gallon, and 1½ ounces each of whole cloves, stick cinnamon and ginger, and allowed to stand overnight. The syrup is drawn off and concentrated to a boiling point of about 219 to 220°F. and returned to the fruit. The fruit and syrup are heated to boiling and sealed boiling hot in jars or cans.

RELISHES

Most commercially prepared relishes are prepared from or contain appreciable amounts of pickled vegetables. Familiar examples of relishes are chow chow, piccallili, Mexican hot and mustard pickles. For recipes and formulas see reference 6 at end of this chapter.

SAUERKRAUT

"Kraut" is made in practically every vegetable growing section of the United States and Europe by a process which is very simple and which can be conducted on either a factory or household scale. It affords a convenient means of conserving surplus cabbage during periods of temporary overproduction.

Coring and Shredding.—Only sound firm heads should be used. The outer leaves are removed by hand, and the core is reamed from the head by a rapidly revolving conical knife. (In some factories the core is not removed.) The cored cabbage is cut into thin shreds by thin, curved knives attached to a revolving metal disc about 3 feet in diameter housed in a vertical metal cylinder into which the heads of cabbage are fed. The sliced cabbage falls on a conveyor which carries it to the fermenting tanks.

Salting.—Cabbage is converted into sauerkraut by a lactic acid fermentation, the presence of a moderate concentration of salt being necessary to reduce the growth of spoilage organisms and to promote the growth of lactic acid bacteria.

The usual proportion of salt is 2½ per cent by weight. The salt is well mixed with the shredded cabbage as the tank or other container is filled.

Large circular wooden vats are used for commercial fermentation and storage and heavy pressure is applied to the cabbage by a false wooden head.

Fermentation.—The pressure and salt extract juice from the cabbage and a brine, which completely covers the cabbage, is soon formed. Bacteria and yeasts develop rapidly and gas evolution is vigorous during the first stages of the fermentation.

Although yeasts are present in considerable numbers and may produce small amounts of alcohol, particularly during the initial stages of the fermentation, the predominant organisms are lactic acid formers; *B. coli* is always present and is responsible for considerable gas formation, but it is present as a contamination and its activities result in injury rather than in benefit to the quality of the "kraut." Butyric acid bacteria are also highly undesirable. If the development of yeasts, *B. coli* and butyric organisms can be prevented, or at least reduced to a minimum, the quality of the product will be improved correspondingly.

Le Fevre[9] recommends the addition of pure cultures of selected lactic acid organisms as a result of an improved product obtained by the use of pure cultures in commercial scale experiments.

The organisms were grown in sterilized cabbage and this in turn was used for the inoculation of tanks of shredded cabbage. He believes that tanks started with pure cultures could be used for the inoculation of subsequent tanks, as is done in the fermentation of vinegar stock, wine, etc., and states that pure cultures are used regularly and with marked success in Europe.

A temperature of 80°F. is the optimum for kraut fermentation. If the cabbage is cold when shredded it is desirable to warm it to 80°F. in the tanks and to warm the fermentation room, if it is very much below 80°F.

The acidity rapidly increases during fermentation and frequently reaches 1.8 per cent expressed as lactic acid. Cabbage contains both ordinary sugars and mannite, which are all fermented to form lactic acid, CO_2, ethyl alcohol and other fermentation products.

Care after Fermentation.—After fermentation is complete the tanks should be sealed to exclude air, the presence of which permits molding, growth of *Mycoderma* and bacterial spoilage. Where a liquid covering only is used this must be skimmed frequently to prevent excessive growth of the destructive film yeast, *Mycoderma.*

Discoloration of Sauerkraut.—Two common forms of discoloration are recognized. One of these is the development of a pink color. the other of a brown color.

The pink color is frequently caused by growth of a pink yeast. Fred and Peterson[7] have made an exhaustive study of this problem and have found normal sauerkraut and pink sauerkraut from the same factory to have the following compositions.

Analysis	Normal Sauerkraut	Pink Sauerkraut
Water	90.600%	88.000%
Volatile acid as acetic	0.247%	0.255%
Fixed acid as lactic	1.026%	1.426%
Alcohol as ethyl alcohol	0.727%	0.978%
Yeast cells per cubic centimeter	3,600,000	91,000,000

The pink sauerkraut contained a very large number of yeast-like cells from which several strains of pigment-forming yeasts were isolated and were used for inoculating shredded cabbage with positive results.

The brown discoloration of sauerkraut usually occurs after removal of the kraut from the vat and is apparently an oxidation phenomenon. Prompt use or canning of the sauerkraut after opening the vat will avoid browning.

Fig. 95.—Heating sauerkraut for canning. (*Courtesy of The Pfaudler Co.*)

Canning.—There is a good demand for canned sauerkraut, since the canned product is in convenient form for shipment and use and is not as subject to deterioration and spoilage as the bulk sauerkraut.

The sauerkraut used for canning is ordinarily not cured for so long a time as that to be sold in bulk, as the canner desires a product of lighter color and lower acidity than the bulk sauerkraut.

It is heated to boiling in steam-jacketed kettles, is packed hot into cans in its own brine (hot fresh brine being added if necessary) and the cans are sealed and sterilized at approximately 230°F. for 60 minutes. The high acidity of the sauerkraut facilitates sterilization, but heat penetration is slow.

Some loss of canned sauerkraut occurs from the development of hydrogen gas by action of the acid of the sauerkraut on the tin plate. A freshly opened can of sauerkraut possesses a disagreeable odor, but this odor disappears during cooking.

PRESERVATION OF OTHER VEGETABLES BY SALTING AND FERMENTATION

In European countries, particularly Holland and Belgium, many varieties of vegetables are preserved commercially and in the home by salting and by fermentation in brine. During the World War these methods were widely advocated by the U. S. Department of Agriculture and State Colleges of Agriculture for use in the home to conserve the surplus of war gardens and to conserve tin plate.

Practically all vegetables can be preserved by mixing with one-fourth their weight of salt or by lactic fermentation in a 5 per cent brine. (For details see reference 5.)

GREEN OLIVES

Spain, France and Italy produce large quantities of pickled green olives, the United States importing from these countries approximately five times as many gallons of green olives as the quantity of ripe olives produced in California.

Varieties.—The Sevillano (Queen) is the largest and most popular olive used for green pickling and the Manzanillo is second in importance. Both varieties have been described in Chapter XII.

Harvesting.—The olives are allowed to attain approximately full size, but are gathered before they have begun to develop color or have softened. Bruising is avoided and the fruit is placed in the pickling vats as promptly as possible.

In some olive sections of Europe if the olives are allowed to remain on the tree too long, they will become infested with the larvae (maggots) of the olive fly.

Lye Treatment.—The olives are placed in shallow vats and covered with a dilute sodium or potassium hydroxide solution (1 to 2 per cent $NaOH$ or KOH) at room temperature. This solution is allowed to penetrate almost, but not completely, to the pits of the fruit.

If the lye solution is too strong or too prolonged all of the bitterness is removed and the flavor, texture and color of the finished pickles are apt to be inferior. By removing the lye solution before it has completely reached the pits a small amount of untreated bitter flesh remains and imparts a pleasing flavor to the pickled olives.

Washing.—The lye is then removed and the olives are covered with water, which is changed several times daily until the fruit is free of lye. Washing will normally require about a week.

Fermentation.—The olives are stored in barrels or large casks in a brine of about 9 per cent salt (36° salometer) in which lactic acid fermentation develops in much the same manner as in dill pickles. The barrels are completely filled with the brine and sealed except for a small vent for escape of gas. In some cases the barrels are placed in the sun in order to elevate the temperature of the brine and promote fermentation. In some cases spices are added to the brine or vinegar in small amounts to improve the flavor and promote a desirable fermentation.

Packing.—The olives are packed in glass or in kegs, usually in the brine in which fermentation has taken place. The brine is, however, brought to about 10 per cent salt (40° salometer) by addition of salt. The olives are not sterilized or pasteurized.

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CHAPTER XXVI

OLIVE AND COCONUT OILS

Olive oil has been the principal fat used in the diet of peoples of the Mediterranean countries since Biblical times. Although most of the olive oil produced in Spain, France, Italy and other olive growing countries is consumed in those countries, a considerable amount is exported to America, England, Germany and other countries which do not produce enough olive oil to supply their own needs.

Coconut oil or "copra" oil is used in enormous quantities in the manufacture of soap and in the preparation of imitation butter; England, Germany, France and the United States being the largest users of this oil.

OLIVE OIL

In Europe olives are grown primarily for oil and pickled olives are of secondary importance, whereas in California the fruit is grown for ripe pickling purposes and only the cull fruit is used for oil making. Consequently the varieties generally grown in Europe are those found best for oil, while in California those best for ripe pickling are grown.

Harvesting.—Olives to be used for oil can be handled somewhat less carefully than those intended for pickling and can often be knocked from the trees with poles and caught on sheets spread on the ground. This method, however, is objectionable because it injures the bearing wood of the tree. Special wooden toothed rakes are better than poles for the purpose.

If the olives are to be crushed within a few days slight bruising does not reduce their value for oil.

Leaves, in so far as is feasible, should be excluded, because during pressing there are extracted from them compounds which injure the quality of the oil.

Olives for oil should be harvested at full maturity. Unripe olives are low in oil and yield an oil deficient in flavor, while over-ripe olives are apt to contain an excessive amount of solid fats (stearin and palmitin) which cause the oil to become cloudy or solidify in the bottle or can during cold weather. In California the fruit is harvested for oil from about Nov. 15 to Jan. 1.

Storage of the Olives.—It is usually impossible in most olive oil factories to crush and press the fruit as rapidly as it is received.

The more carefully the olives are harvested, the better and longer they will keep. Bruised and broken fruit molds and ferments quickly. Molding is a more serious defect than fermentation, because it is more difficult to rid an oil of a moldy than of a fermented flavor.

In Europe the fruit is placed in large bins or in large heaps on the floor. Fermentation by bacteria occurs in the tightly packed fruit; the olives give up much of their moisture and become shriveled in appearance. The temperature rises because of the heat generated by the fermentation, and there develops a peculiar "silage" odor and flavor which persists in the oil.

Olives are in some cases stored in shallow layers on large wooden trays where circulation of the air prevents mold growth and partially dries the fruit, but the method is too expensive for general use.

In Spain it is said that oil olives are sometimes preserved by mixing the fruit with a small amount of dry salt in bins. The salt is for the purpose of preventing mold growth and undesirable bacterial fermentation.

In California olives to be used for oil are generally stored in brine, as for pickling (see Chapter XII).

Washing.—It is desirable that the fruit be washed to remove adhering soil and leaves before crushing. Sprays of water can be used to advantage for this purpose.

Sanitation in the Olive Oil Factory.—Olive oil absorbs odors and flavors rapidly and once acquired by the oil they are extremely difficult to remove or correct. Press cloths become rancid unless kept scrupulously clean. Press cake (pomace) soon becomes moldy and the odor may be absorbed by oil stored in the vicinity. Crude oil, smoke and other odoriferous materials should not be allowed to contaminate the oil. Floors, bins, conveyors, filters and other equipment with which the fruit comes in contact must be kept clean and free from rancidifying oil. Washing floors and equipment with hot sodium carbonate solution occasionally will remove rancid oil or other adhering vegetable matter. Press cloths should at the end of the season be boiled with such a solution to remove all oil.

First Crushing.—In California the olives are crushed between revolving steel rolls of the type used for the crushing of barley and the seeds of the fruit for the most part escape crushing.

The fruit is elevated to a hopper above the crusher rolls and after passing through the crusher is collected in press cloths spread beneath the rolls (see Fig. 96).

First Pressing.—The first pressing is made in a rack and cloth press similar in appearance to the apple press described in the chapter on juices. Very heavy folded cloths containing the crushed fruit to a depth of about 3 inches are placed between woven metal racks or heavy wooden racks (see Fig. 96).

FIG. 96.—At left: Building up crushed olives in cloths and racks. At right: Pressing.

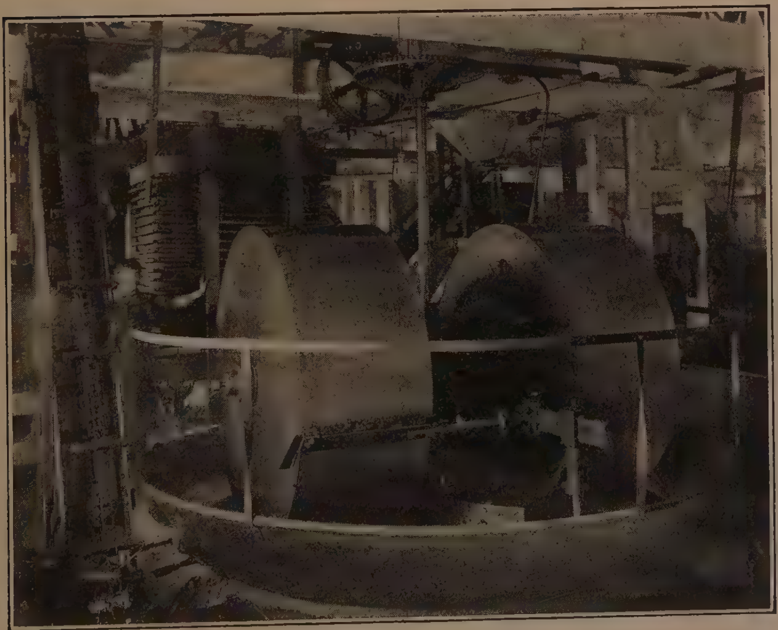

FIG. 97.—Edge runner for grinding pressed olives.

Pressure is applied by means of a hydraulic or a gear-driven press. The pressure indicated in the cylinder head on the press during the first pressing is 400 to 500 pounds per square inch.

The first pressing extracts most of the juice and a small proportion of the oil. The oil obtained by the first pressing is known as "virgin" oil and is considered superior in flavor and general quality to that obtained by subsequent pressings.

Second Crushing.—The pomace from the first pressing is placed in a machine known as an edge roller, consisting of a large cast-steel bowl in which revolve two heavy steel or stone wheels (see Fig. 97). The pulp is thoroughly crushed and some of the seeds are broken.

Second Pressing.—The crushed fruit is again placed in press cloths and subjected to a second pressing, usually in a more powerful press than that used for the first pressing. The pressure indicated on the pressure gauge on the hydraulic press cylinder is usually about 1,500 pounds per square inch.

The second pressing extracts most of the oil, the oil and juice being collected in a tank below the press and pumped to settling tanks. First and second pressing oils are usually combined.

Third Crushing.—The pomace from the second pressing is broken up, again placed in the edge runner and a small amount of hot water is added to facilitate crushing and pressing. Most of the seeds are broken and the kernels crushed.

Third Pressing.—A relatively small amount of oil is obtained by the third pressing and it consists of oil from the flesh admixed with considerable oil from the seeds. The seed oil is inferior in quality to the oil obtained from the flesh and contains an enzyme which hastens rancidification. The hot water added at the time of the third crushing melts the solid fats and the expressed oil also carries a larger percentage of these solid fats than does oil from either the first or second pressings.

For these reasons the oil obtained by the third pressing is usually not mixed with that from the first and second pressings.

European Methods.—In European countries press cloths made of tough grass fiber are used and pressure is often applied by means of a screw press operated by hand.

Much of the European oil is made in small factories operated by growers, and the oil so made is often very inferior because of molding or fermentation of the fruit before crushing and pressing and because of carelessness in handling the expressed oil. The oil is delivered to centrally located refineries where any disagreeable odors and flavors are removed and the refined oils blended with high-quality oils.

The Lucca district in Italy is particularly famous for its oil refineries. Marseilles in France and Seville in Spain are also important olive oil refining centers.

Other Methods of Extracting Olive Oil.—Shaw[1] states that in Algiers and other oil producing countries of the Mediterranean region, oil is recovered in some factories by separating the seeds from the pulp, grinding the pulp finely and separating the pulp, juice and oil by use of a centrifuge.

Recently a California oil manufacturing concern has developed a process in which the olives are passed through a tomato pulper equipped with a very heavy screen to separate the pulp from the seeds. The resulting "puree" is mixed with warm water and the oil is separated from the juice and pulp in a high-speed cream separator.

According to Bioletti and Oglesby,[2] in a process known as the "Acapulco system" the seeds are separated from the pulp, the pulp is finely ground, mixed with warm water and subjected to a vacuum. The oil is said to collect on the surface of the mixture and can be recovered by skimming.

A continuous olive oil press similar in design to the oil expeller used for the extraction of oil from copra and other dry oil-bearing materials can be used satisfactorily, if the fruit is dried before pressing.

Separation of Oil and Black Liquor.—The oil and juice ("black liquor") are pumped from the oil pressing tank to tall cylindrical tin or galvanized iron tanks to permit settling and separation of the juice and oil.

The settling tanks hold 300 to 800 gallons each and are equipped with conical or sloping bottoms so that the oil and juice can be separated sharply by drawing off the juice through a faucet. Some factories use a tank in which the oil and juice are separated continuously immediately after pressing, the juice flowing continuously from an outlet at the bottom of the tank and the oil flowing from an outlet near the top.

Washing the Oil.—Freshly expressed olive oil contains a considerable amount of bitterness, which is more soluble in water than in oil, and on this fact depends the method of removal of the bitterness from the oil.

In the simplest form of oil-washing device the oil is placed in a tin or galvanized iron tank and warm water is sprayed on the surface of the oil dissolving the bitterness as it flows downward. The process can be made continuous. In some factories the oil is sprayed upward into a tank of warm water and may be recovered by skimming or may be allowed to overflow from the tank into a suitable conduit. Theoretically this method should be more effective than spraying the water into the oil, because each oil droplet is surrounded by an excess of water when the oil is sprayed upward into water. The water used is maintained at 90 to 100°F.

Preliminary Settling.—The washed oil is cloudy and contains a considerable quantity of pulp and some emulsified water. Settling for 10 or 12 days in tall cylindrical tanks permits deposition of much of this suspended matter and separation of some of the excess solid fats. The settlings, "foots," can be removed by drawing off through a faucet.

The foots can be sold for soap stock or filtered to recover an appreciable percentage of oil.

First Filtration.—The settled oil is cloudy and contains some water and should be filtered before storage, to remove the water and solid impurities. In one California factory this is done by mixing the oil with infusorial earth and filtering through canvas filter bags. Filtration is rapid and the equipment is inexpensive. A fairly clear oil is obtained and most of the water and solid impurities are removed.

A filter press can be used successfully for the first filtration if so desired, particularly if infusorial earth is mixed with the oil.

Aging.—Like new wine, fresh olive oil is not pleasing in flavor and must be aged before it is ready for bottling or canning.

In California the oil is placed in galvanized iron or tin tanks holding about 1,000 gallons each.

In some European and Algerian factories glass-lined concrete tanks or large earthenware pots or tanks are used for storage of the oil during settling. The oil tanks should be constructed of materials that will not absorb the oil.

Final Filtration of the Oil.—In most California factories the oil is filtered through folded filter paper in tin funnels, as many as 500 to 600 filters being used in a single factory. This method of filtration is slow and costly of labor, but produces a brilliantly clear oil.

Several factories in California are equipped with filter presses in which pieces of heavy filter paper are used in the filter frames. The oil is forced through the filters by a pump or by gravity. Filtration is facilitated and the clearness of the filtrate increased if a small amount of infusorial earth is added to the oil before filtration.

Removal of Excess Color.—Often olive oil is too dark in color to be merchantable. The excess color can be removed by mixing the oil with finely ground bone black or vegetable decolorizing carbon or with fullers' earth. Decolorization is hastened by heating the mixture to 175 to 190°F. for 30 to 60 minutes before filtration. If the oil becomes too light in color it may be blended with oil of darker color to obtain the desired tint.

Refining of Spoiled Olive Oils.—Olive oil made from moldy or fermented fruit frequently possesses a disagreeable odor or flavor, or both. Oil frequently becomes rancid, that is, the olein decomposes into free oleic acid and glycerin, with the development of the well-known odor and flavor of rancid oil. It is possible in most cases to remove objectionable odors and flavors and to neutralize and remove free fatty acids. The treatment will vary with the character and the degree of decomposition.

Removal of Free Acid.—Oil which has merely become rancid without the absorption of foreign odors or flavors can usually be rendered

edible by neutralization of the free fatty acid with sodium carbonate or other alkali.

From the titration of the free fatty acid the amount of alkali required to neutralize the acidity of the lot of oil requiring treatment can be calculated. The required amount of sodium carbonate can then be mixed with the oil, the mixture heated gently to facilitate neutralization and the neutralized oil cooled and filtered. Approximately 5.3 grams of sodium carbonate will be required for each 28.2 grams of free oleic acid.

Removal of "Off" Odors and Flavors.—If the oil has been made from moldy or fermented fruit or has acquired disagreeable odors or flavors in other ways the treatment described above will not be adequate. Usually adding 1 to 2 per cent of bone black to absorb disagreeable flavors, heating to 190°F. and washing with a stream of carbon dioxide for 2 to 3 hours will remove objectionable odors and flavors.

In some cases it becomes necessary to treat the oil with superheated steam under a vacuum, a treatment that will usually remove odors that cannot be removed by other means. Some oils are deodorized by heating at atmospheric pressure and treating with a stream of air for several hours. Disagreeable odors and flavors may also be removed from olive oil and other edible oils by washing with ethyl alcohol.

The Properties of Olive Oil.—Olive oil consists of appoximately 70 per cent olein (the triglyceride of oleic acid), $C_3H_5(C_{17}H_{33}CO_2)_3$, approximately 27 to 28 per cent palmitin, $C_3H_5(C_{15}H_{31}CO_2)_3$, some stearin, $C_3H_5(C_{17}H_{35}CO_2)_3$, and a small amount of linolein. Stearin and palmitin are solid fats and are the cause of the turbidity of olive oil during cold weather.

The specific gravity of olive oil is 0.914 to 0.918 and its saponification value is 190 to 195. Good-quality oil solidifies at approximately 2 to 5°C.; oils containing an excessive amount of solid fats solidify at higher temperatures. The iodine value for olive oil is 79 to 93. The refractive index at 15°C. is 1.47.

Olive oil is often adulterated with cottonseed and other cheap oils but added cottonseed oil can usually be detected by the Halphen test, which consists in heating the oil with a mixture of equal parts of amyl alcohol and carbon bisulphide, the latter containing 1 per cent of free sulphur. An orange-red coloration develops if cottonseed oil is present. Characteristic tests are also available for the detection of other edible oils used in adulterating olive oil.

Yield of Oil.—From 35 to 45 gallons of oil per ton is obtained in California from the Mission variety and less from other varieties.

By-products.—The pomace from olive oil manufacture contains an appreciable amount of oil. Analyses of a large number of samples from oil mills in California by A. W. Christie and the writer demonstrated the presence of 7 to 16 per cent of oil in the air-dried pomace. This

corresponds to about 19 to 42 gallons of oil per ton of pomace. The average oil content was approximately 10 per cent. Most of the pomace in California is utilized for fuel, no attempt being made to recover oil.

It was found that most of this residual oil could be recovered by extraction with various fat solvents, such as ether, benzol, chloroform, carbon bisulphide and gasoline.

In European countries in which olive oil is produced, the pomace is extracted with a volatile solvent and the oil so recovered is refined and sold for soap manufacture or other industrial purposes. It is stated that some of this solvent oil, when highly refined, is blended with oil obtained by pressing and is sold as edible oil.

COCONUT OIL

The United States imports in excess of 500,000,000 pounds of copra (dried coconut meat) annually and the world production of copra is about 1,500,000,000 pounds. The copra is used for the production of coconut oil, one of the principal oils used in the manufacture of soap and oleomargarine.

Harvesting and Drying Coconuts.—Selected varieties of coconut palms are grown in large plantations in the tropics. Natives harvest the fruit and transport it to centrally located drying depots.

Usually the nuts are cut or broken open by hatchets, and the juice ("milk") is generally wasted, although it contains fermentable sugar and can be used as a source of alcohol or vinegar or can be condensed to a syrup.

The fruit is spread on trays in the sun to dry. During drying the meat loses about 50 per cent of its weight and becomes loosened from the shell. When dry the meat and shell are readily separated. In some drying depots the meat is separated from the shell before drying. The dried meat "copra" is shipped in bulk by vessel to American or European ports.

Sun drying results in decomposition of a large proportion of the oil by fungi and by the action of sunlight. Twenty per cent of free fatty acid in the expressed oil is not uncommon. Decomposition often occurs, also, during water shipment, because of conditions favorable to mold development in the damp holds of ships.

Some copra is made by drying the nuts by artificial heat but usually the dryers are poorly designed and smoky. Undoubtedly there is need for the installation of efficient, modern dehydraters for drying copra for oil purposes. Drying of coconut for culinary purposes is conducted in well-built and carefully operated dryers, but such equipment is probably too costly for drying copra for soap oil manufacture.

The yield of copra is approximately 1,200 pounds per ton of fresh coconut meat.

Composition of Copra.—Copra contains about 60 to 65 per cent of oil. That containing more than 6 per cent moisture rancidifies quickly.

Removal of Refuse.—At the oil factory the copra passes over a broad belt where large pieces of shell, wood, rocks, etc., are removed by hand. A magnet at the end of the belt removes nails, bolts and other scraps of iron which if not removed might wreck the shredding machines.

Shredding.—To facilitate pressing, the copra is shredded mechanically or ground between fluted rollers.

Heating.—The shredded copra is heated by steam to soften the oil, since coconut "oil" (palmitin) is at normal temperatures a solid fat.

Pressing.—The heated material is pressed in an expeller, a heavy-duty continuous screw press, which extracts the oil to the point where the press cake contains about 8 per cent of oil.

The cake is ground and again heated and is then pressed in cloths in a hydraulic press.

From 1,100 to 1,300 pounds of oil per ton is recovered by the two pressings.

Disposal of Press Cake.—The press cake, amounting to about 700 to 800 pounds per ton of copra, is high in protein and feeding value. It is ground to a coarse meal, sacked and sold to dairymen and other stock raisers.

Uses of Edible Coconut Oil.—Deodorized refined oil is sold to manufacturers of imitation butter ("nut oleomargarine") who "churn" it with sour milk, cool and crystallize it and mold it in butter forms. The oil is used also in lard substitutes. It is not as satisfactory as other fats for frying because of its odor and tendency to decompose at high temperatures.

Shipment of Oil.—The oil is usually shipped in tank cars holding about 10,000 gallons of oil each. It is pumped into the tanks while warm and solidifies on cooling, and is melted by steam when it is to be removed.

Refining.—The free fatty acid (often equal to 20 to 30 per cent of the total oil) is neutralized by heating with the required amount of concentrated NaOH or Na_2CO_3. The resulting soap is recovered and sold to soap factories. If an emulsion forms it can usually be broken by the addition of heavy brine.

The oil is decolorized by passage through steel towers filled with coarsely ground bone coal, heated with steam coils to prevent solidification of the oil. The decolorized oil is then filtered by means of filter presses.

The oil may be deodorized by treatment with superheated steam in vacuo or by blowing the warm oil with a stream of air or carbon dioxide or by washing with ethyl alcohol.

Properties of Coconut Oil.—Coconut oil consists chiefly of palmitin, $C_3H_5(OC_{15}H_3CO)_3$, laurin, $C_3H_5(OC_{13}H_{23}CO)_3$, and myristin, C_3H_5

$(OC_{13}H_{27}CO)_3$. It also contains small amounts of other oils. High-quality edible coconut oil must contain less than 0.1 per cent of free fatty acid.

The melting point of coconut oil is 23 to 26°C.; specific gravity at 100°C., 0.86 to 0.9; saponification value, 250 to 260; and refractive index at 60°C. is 1.43.

At ordinary temperatures it is solid, although in very warm weather it becomes liquid, and possesses the characteristic coconut flavor unless deodorized.

Coconut oil is unstable and becomes rancid more rapidly than many other vegetable oils.

Hydrogenation.—Liquid oils can be transformed into solid fats by reduction with hydrogen. Thus, olein (of cottonseed oil) can be converted into stearin according to the following reaction:

$$\underset{\text{Olein}}{C_3H_5(C_{17}H_{33}CO_2)_3} + 3H_2 = \underset{\text{Stearin}}{C_3H_5(C_{17}H_{35}CO_2)_3}$$

This reaction is known as "hydrogenation."

Hydrogenation is accomplished by heating the oil, usually in an autoclave under pressure, to 150 to 250°C. with hydrogen gas and a finely divided catalyser, such as specially prepared nickel or platinum.

Hydrogen used for oil treatment must be very pure and free from catalyst "poisons" (inactivators), such as hydrogen sulphide, arsenic, etc. Electrolytic hydrogen from the electrolysis of water is the purest hydrogen gas obtainable, but is more expensive than that obtained by reducing water vapor over pure spongy iron.

Most oils lose practically all their odor during hydrogenation; thus, fish oil loses much of its "fishiness" and copra oil most of its coconut odor and flavor.

Oils to be hydrogenated must be practically free from free fatty acid. For details of hydrogenation see reference 5 at end of this chapter.

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CHAPTER XXVII

UTILIZATION OF WASTE FRUITS AND VEGETABLES

In the canning, drying and preserving of fruits and vegetables there accumulate peels, cores, pits, vines, cobs and other waste materials which must either be utilized in some manner for by-products, fed to livestock, or disposed of as garbage.

The utilization of fruit pits has become an important industry in California and at present nearly all of the apricot pits from the drying and canning industries are converted into valuable by-products.

Character of Fruit and Vegetable Wastes.—The more important wastes are the following:

A. Fruit Wastes:
1. Peels, cores and trimmings.
2. Pits from apricots, cherries and peaches.
3. Grape seeds, stems and skins.
4. Cull fruit from fresh fruit packing houses.
5. Over-ripe and blemished fruit from canneries, dryers, etc.

B. Vegetable Wastes:
1. Tomato seeds, skins and trimmings.
2. Asparagus waste from canning.
3. Cobs and husks from corn canning.
4. Vines and pods from pea canning.
5. Wastes from canning or drying miscellaneous vegetables, such as spinach, pumpkin, sweet potatoes and beans.

Cereal wastes, such as cottonseeds, corn germs and wastes from fish and meat packing, could also be added to the list, but these do not come within the scope of this book.

FRUIT BY-PRODUCTS

The utilization of waste and cull fruit in the preparation of certain products is discussed in other chapters. Among the products made from such fruit may be mentioned jams, jellies, juices and vinegar (see Chapters XV, XVI, XVII and XVIII).

Fruit Peels and Cores.—A large part of the cores from apple canneries and dryers are now utilized for the manufacture of vinegar or for jelly stock. If this material is to be used for vinegar it should be crushed and

pressed within a few hours after the fruit is peeled, so that loss of sugar does not result by wild yeast fermentation and an excessive amount of acetic acid is not developed by the activity of acetic acid bacteria. (For details of vinegar manufacture see Chapter XXIV.)

Jelly Base.—Apple cores and peels are often dried and sold to jelly factories. The dried material is refreshed in water and boiled to extract pectin and the resulting extract is combined with various fruit juices or pulp in preparing cheap jellies and jams. The dried waste is also used as a raw material for the preparation of powdered pectin and pectin concentrates. (See Chapter XVII for further details.)

Utilization of Pineapple Waste.—As previously outlined, pineapple peels and cores from canning are now utilized in several ways, discussed in Chapter XI, or for vinegar.

Much of the juice is fermented for the manufacture of alcohol, denatured by the addition of wood alcohol and ether. Ether is added to the denatured alcohol for the purpose of rendering the mixture more explosive for use in automobile engines.

Pineapple cores are now candied and exported to the mainland of the United States for the use of confectioners.

Fruit Pits.—In the canning of peaches, apricots and cherries, a large quantity of waste pits is obtained. These are utilized in Germany and the United States for the manufacture of a fixed oil, bitter almond oil and macaroon paste.

Apricots, prunes, cherries, peaches and almonds are botanically closely related, all being members of closely related genera of the family *Drupaceae*. The fixed oils and bitter almond oil obtained from the kernels of these various fruits are practically identical in composition, the bitter principle in all cases being amygdalin.

Separation of Pits and Kernels.—The kernels contain the most valuable constituents of fruit pits and the first step in their utilization is the separation of the kernels from the shells. Apricot, bitter almond, cherry and prune pits are easily crushed between heavy iron rollers so adjusted that the pits are broken and the kernels not crushed. The broken pits and kernels drop from the crusher into a tank of brine of such concentration that the kernels float and the shells sink.

The kernels are skimmed from the surface of the brine by a mechanical device and are sprayed with water to remove excess salt. They are then dried, cleaned by grain-cleaning machinery to remove shriveled kernels and other refuse and sorted by hand on belts to remove pieces of shell, moldy kernels and other objectionable material not removed by the cleaning machine.

Yields of Kernels.—Apricot pits yield about 23 to 24 per cent of kernels and peaches about 7 per cent. Peach pits are difficult to crack and the kernels are difficult to recover, a large percentage of the kernels

being poorly developed or dried and devoid of oil. Cherry pits according to Rabak yield about 28 per cent of kernels. Prune pits yielded about 10 to 15 per cent of kernels in laboratory tests made at the University of California.

Expressing the Fixed Oil.—The fixed oil is the most valuable constituent of these waste pits. It is generally recovered by pressure but may also be extracted by the use of volatile solvents. If solvents are used the resulting oil is usually only fit for soap stock.

The kernels are coarsely ground to facilitate pressing, heated to near the temperature of boiling water by steam or by passage through a steam-jacketed tube and pressed by a continuous press known as an expeller or by a press in which cloths and racks are used as in the pressing of olives.

Expressing Oil by Expeller.—The continuous press is inexpensive to operate, but gives a cloudier oil and lower yield than pressing between cloths and racks; nevertheless it is the one generally used in expressing oil from seeds. It consists of a horizontal, perforated, heavy metal cylinder fitted with a screw conveyor. The kernels enter the press through a hopper at one end of the cylinder and are conveyed by means of the screw toward the opposite end of the cylinder and over a heavy metal cone projecting into the cylinder. As the diameter of the cone increases, the pressure applied to the kernels increases. The pressure can be adjusted by decreasing or increasing the size of the outlet and the distance between the walls of the cylinder and the cone. The press cake passes out over the cone and the oil flows through perforations in the floor of the press cylinder. The press cake is ground and pressed a second time to recover as much of the oil as possible.

Use of Hydraulic Presses.—In using hydraulic presses the kernels are prepared as for pressure in the expeller, the heated ground kernels are packed in heavy press cloths usually made of camel's hair; steel plates are placed between each pair of cloths and a pressure of 3 to 5 tons per square inch is applied. The press cake should be reground and pressed a second time.

Yields.—From apricot kernels a yield of at least 33 per cent of oil should be obtained, from peaches about 25 per cent and from cherries and prunes about 30 per cent.

Refining the Fixed Oil.—The oil contains considerable solid material, such as particles of kernels and kernel skins. These can be removed by screening or coarse filtration.

The raw oil is often high in free fatty acid, dark in color and rancid in flavor and it is necessary to refine it. This can be done by treatment with a small amount of sodium carbonate to neutralize the free acid, by the addition of a decolorizing agent such as bone black or fuller's earth and by heating to volatilize objectionable odors.

Titration of the acidity and laboratory trials with small measured volumes of the crude oil will determine the quantities of sodium carbonate and bone black or fuller's earth that must be used. Usually 2 to 3 per cent of powdered bone black or finely ground vegetable decolorizing charcoal will be sufficient. The oil is generally not bleached water-white, but is usually decolorized only to a light straw color.

The reaction between the fatty acid and the carbonate is facilitated by the presence of about ½ per cent of water and heat is necessary for the best results. In one factory in California which is no longer in operation, the mixture of bone black, sodium carbonate, oil and about 0.5 per cent water was heated to about 190 to 200°F. The mixture was then mechanically agitated and a stream of carbon dioxide was passed through the oil to remove objectionable odors by volatilization. After several hours' treatment the oil was allowed to settle and was filtered. The finished oil was nearly colorless and was of pleasing flavor and odor. Deodorization can also be accomplished by treatment with steam under vacuum.

The refined oil finds a market for use in the preparation of face creams and pharmaceuticals, but is also an excellent table oil and is used extensively in California in the canning of sardines.

Composition of the Fixed Oil.—The fixed oils from apricots, sweet almonds, bitter almonds, peach kernels, prune kernels and cherry kernels are practically identical in composition. The principal compound present in these oils is olein, $C_3H_5(C_{17}H_{33}CO_2)_3$. There are also present small amounts of stearin and palmitin, both of which are solid fats.

Bitter Almond Oil from Press Cake.—The press cake remaining from the extraction of the sweet oil contains the bitter principal, amygdalin, and an enzyme, emulsin, which has the power of converting amygdalin into benzaldehyde, glucose and hydrocyanic acid, according to the following reaction.

$$C_{20}H_{27}O_{11}N + 2H_2O = C_6H_5CH{:}O + HCN + 2C_6H_{12}O_6$$

Benzaldehyde imparts the characteristic odor and flavor to bitter almond oil and to flavoring extracts such as "wild cherry." Artificial bitter almond oil and flavoring extracts are commonly made from benzaldehyde synthesized from benzene, a coal tar product, and a bitter almond oil from fruit kernels is frequently adulterated with the synthetic benzaldehyde.

Hydrolysis of Amygdalin.—The press cake is heated with about 12 volumes of water to soften the ground kernels and to extract the amygdalin. The heating may destroy most of the enzyme emulsin, making it necessary to add to the mixture of water and kernels freshly ground unheated kernels equal to about 10 per cent of the press cake to hydrolyze the amygdalin. The mixture is warmed to a temperature of about 50°C. (122°F.) for an hour or less. Hydrolysis can also be conducted

at room temperature but at least 12 hours should be allowed at this temperature.

If the kernels are not heated to a high enough temperature before pressing to destroy the enzyme emulsin, the press cake does not require the addition of unheated kernels to cause hydrolysis of the amygdalin. This method is used successfully in one California oil factory.

Distillation.—Benzaldehyde boils at 179°C. and in order to separate it from the water and kernels it is necessary to distill it from the mixture with a current of steam, which is done by placing the mixture of kernels, water, etc., in an enclosed metal tank, passing a current of steam through the mixture and condensing the vapors by a water-cooled condenser. There should not be any open outlets from the distillation apparatus within the distillation room, because of danger of poisoning from the hydrocyanic acid which distills with the water and benzaldehyde. The bitter almond oil settles to the bottom of the vessel in which the distillate is collected and can be easily separated from the water which distills with it. It contains from 2 to 4 per cent of prussic acid, and if the oil is to be used for medicinal purposes the prussic acid is not removed.

Refining.—If to be used as a flavoring material most of the prussic acid must be removed from the bitter almond oil. This can be done by heating with slaked lime and an iron salt or by treating with sodium bisulphite. It is necessary to redistill the benzaldehyde from the reaction mixture.

Rabak[1] obtained from peach kernels, 0.7 per cent of bitter almond oil; from apricot kernels, 1.6 to 0.8 per cent; from prune kernels, 0.3 to 0.46 per cent; and from cherry kernel press cake, 0.95 per cent. The yield from the press cake is nearly 50 per cent greater than from the fresh kernels, because of concentration of amygdalin in the cake, by expression of oil.

Macaroon Paste.—Macaroon paste is used extensively by bakers. Although some macaroon paste is made from sweet almonds, much of this product now used by American bakers is prepared from apricot kernels.

In one method of preparing macaroon paste the kernels are first blanched, *i.e.*, heated in water a short time to soften and loosen the skins, and are then peeled mechanically. The temperature used should be such that the emulsin is not injured. The peeled kernels are ground and heated with water to cause hydrolysis of the amygdalin. The resulting benzaldehyde and prussic acid are removed by steam distillation and the residual meal is separated from the excess water by treatment in a filter press. It can then be mixed with cane sugar and heated in a steam-jacketed kettle to remove excess water. The resulting paste is sealed hot in cans.

Another process consists in removing the skins from the kernels; heating the kernels in water to hydrolyze the amygdalin, drying the

hydrolized kernels to expel benzaldehyde and prussic acid and finally grinding the deamygdalinized kernels with sugar to give a paste.

Press Cake Meal.—The press cake, after grinding and distillation with steam for recovery of the bitter almond oil, can be separated by pressing from the water with which it is associated and used for a stock food, high in protein and carbohydrates. Rabak[1] found cherry kernel press cake to contain 30.87 per cent protein, 42.13 per cent nitrogen-free extract, 8.9 per cent crude fiber and 13.1 per cent ether extract. It was richer in protein than coconut meal but contained less protein than cottonseed meal. Analyses of apricot, peach and prune kernel meals are not given, but these are probably of approximately the same composition as cherry pit meal.

The solution left in the still after distillation, according to Rabak,[1] contains approximately 6 per cent by weight of the original press cake, which can be evaporated to dryness and incorporated with the dried and ground press cake.

Waste from Grape Juice Factories.—In the preparation of grape juice and wine, grape stems and grape pomace are obtained as waste products. The pomace consists of the pressed skins and seeds. In most grape juice plants little effort is made to utilize these waste materials.

Stems.—Grape stems, separated from the grapes at the time of crushing, as described in Chapter XV, normally constitute approximately 5 per cent of the original weight of the grapes. Rabak[3] finds that the Concord grape stems yield about 2 per cent of cream of tartar when chopped in short lengths or ground and extracted with boiling water. The watery extract is concentrated by boiling and allowed to cool and stand 24 hours or longer. Cream of tartar (potassium acid tartrate) separates as crude crystals which can be purified by redissolving in water and recrystallizing. The watery extract was too low in tannin to warrant concentration.

Separating Seeds and Skins.—The pomace consists of seeds and skins which must be separated before the seeds are used for oil. Rabak[3] found that the separation could be made fairly satisfactorily by screening out the seeds after passing the wet pomace through a pomace picker, such as is used in the vinegar industry, and through an apple grater to break up the press cake thoroughly. The seeds fall through a quarter-inch screen and the skins are retained.

If the pomace is dried thoroughly before screening an almost perfect separation of the skins and seeds can be made by screening and fanning.

Drying can be economically accomplished in rotating cylinders heated by a blast of air or steam pipes.

Recovery of Oil.—The seeds are ground and the oil extracted by means of an expeller as described for the extraction of oil from fruit kernels and a yield of 10 to 15 per cent obtained. More satisfactory

results are obtained if the seeds are decorticated (hulled) before pressing. This is accomplished by crushing the seeds lightly between rolls, and screening and fanning to remove the hulls. The kernels may be ground and pressed, or pressed direct without grinding. If decortication is not accomplished, the hulls cause excessive wear on the expeller and high percentage of crude fiber in the press cake which greatly impairs its value as a stock food.

In a California grape seed by-products factory the ground seeds are pressed in hydraulic presses between heavy cloths and steel plates.

In Europe the oil in some factories is recovered by extraction with a volatile solvent, such as benzine, gasoline or carbon bisulphide, but it is difficult to remove all trace of the solvent from the oil and it is generally only suitable for soap making. Extraction with solvents is conducted in tall steel tanks, a battery of several tanks in series being used. The residue from solvent extraction is usually not suitable for stock food and can only be utilized as a fertilizer; whereas the press cake from an expeller or hydraulic press can be used to good advantage as stock food. Solvent oil can be deodorized by treatment with steam in vacuo, but the deodorized oil is not of high enough quality for use as food.

Tannin from Hulls.—The hulls from the decortication of grape seeds contain a large percentage of tannin, which can be extracted by boiling with water and concentrated to a heavy syrup. Rabak[3] has found such a product suitable for the tanning of hides. A yield of 10 per cent of syrup containing 15.5 per cent of tannin was obtained from the hulls.

Jelly from Grape Skins.—Grape skins, and the whole grape pomace as well, were found suitable, by Rabak,[3] for the preparation of jelly and jelly stock, by the usual methods described in Chapter XVII. An average of 24 ounces of jelly was obtained from each pound of pomace.

Character of Grape Seed Oil.—Grape seed oil is a semi-drying oil, resembling soy bean oil in this respect, and on this account can be used in paints. If to be used as a table oil, it must be refined by treatment with sodium carbonate or other alkaline material, to remove free fatty acids, and with bone black or fuller's earth, to remove excess color. See paragraphs on refining of olive and coconut oils in Chapter XXVI.

Value of Press Cake.—The press cake is suitable for stock food, although it is desirable to mix with it bran or alfalfa meal or similar material to reduce the tannin content of the mixture at the time of feeding. The press cake is very high in crude fiber, an objectionable feature from the standpoint of its value as stock food. According to Rabak,[3] press cake from the decorticated seeds in his experiments contained 4.48 per cent fat, 14 per cent protein, 29.7 per cent nitrogen-free extract (starch, etc.), and 43.2 per cent crude fiber, thus comparing favorably with other seed meals in feeding value.

Raisin Seeds.—In the packing of Muscat raisins in California the waste seeds constitute about 8 to 12 per cent of the original weight of the raisins, or a total of about 5,000 tons annually. Adhering to the seeds is a considerable amount of pulp and syrup, which contains sugar equal to about 20 per cent of the weight of the seeds, and the seeds contain oil and tannin, both valuable constituents.

Recovery of Syrup.—The freshly separated seeds soon develop fermentation and become moldy, if allowed to stand. It is therefore necessary to treat them at once if the sugar is to be recovered or utilized.

The seeds may be washed with warm water to dissolve the sugar from the adhering pulp and syrup. The solution, which contains sugar and other grape solids, can then be filtered and concentrated in a vacuum pan to a syrup of the desired density for table use, baking, etc.

Alcohol and Vinegar.—The sugary extract from the seeds can be fermented with yeast and distilled to obtain ethyl alcohol. This is being done at present to a limited extent in a by-products factory in Fresno, Cal., although there is little demand for the product at present.

The alcoholic distillate may be diluted to about 10 per cent alcohol and acetified in vinegar generators to give a distilled vinegar of good quality suitable for preservation of pickles or for table use.

Fixed Oil.—The washed seeds are dried in a rotary dryer in a blast of hot air and crushed and pressed in hydraulic presses, although expellers could be utilized to good advantage. The yields of oil, its chemical composition and general qualities are very similar to those noted previously for oil from grape seeds obtained from pomace from grape juice factories and wineries. At present the oil is sold for industrial purposes only, *i.e.*, for soap making, paints, etc.

When properly refined, raisin seed oil can be made into a very palatable table oil.

Some of the press cake is sold for stock food but is very high in tannin and should be mixed with other feeds before use. However, most of the cake is now sold for fuel.

Raisin Stems.—Waste stems from the stemming of raisins in California are now utilized for fertilizer, their principal fertilizing ingredient being potassium. They are dried, ground and applied to the soil with or without the addition of other substances. There is a total of approximately 7,800 tons of stems available in California annually.

The stems may be utilized for recovery of cream of tartar and tannin.

Utilization of Cull Fruits.—The utilization of cull fruit of sound quality is a much more important and broader problem than the utilization of fruit wastes, such as peels, cores, etc. Such fruit can be utilized in many ways, as for dehydration, and the preparation of jams, jellies, preserves, candied fruits, vinegar, denatured alcohol, juices and syrups. These

processes and products are fully described in other chapters to which the reader is referred.

Citrus by-products are discussed in a separate chapter devoted to that subject (see Chapter XXVIII).

The lower grades of canned fruits (in California, "Pie" and "Seconds)" should be utilized for drying, preparation of jams, preserves, candy centers, etc., rather than for canning, because marketing such fruit in canned form reacts unfavorably upon the sale of the better grades.

There is little demand for the small sizes of dried prunes and Muscat raisins. Small prunes are pitted and sold to bakers for use in pies, cakes, bread, etc. Small Muscat raisins are now seeded and canned and some of the small raisins are used for the preparation of syrup and alcohol.

Waste Juices from Canning.—In the pitting of cherries a large amount of juice accumulates and is generally not utilized. Rabak[4] estimates the juice so obtained at 70 gallons per ton of fresh cherries. It could be collected, heated, filtered and added to the syrups used in canning cherries.

The juice is also suitable for the manufacture of vinegar or denatured alcohol, or when partially neutralized with calcium carbonate and concentrated in vacuo, yields a palatable table syrup. It may also be combined with pectin and sugar to give jelly.

Waste Syrup from Canning.—It is estimated that the waste of syrup from sealing and syruping machines in an eight-line fruit cannery involves a loss of 400 to 700 pounds of sugar per day. In the past this syrup has not been recovered in most canneries. A system and a machine have recently been developed by Hiller of San José for the recovery and refining of such waste syrup. The syrup is gathered in drains beneath the syruping and sealing machines and is pumped to the refining equipment, where it is mixed and heated with bone black and is filtered in a small filter press. The syrup is freed of oil, color and objectionable flavor by the refining process and can be used in canning.

Olive By-products.—In California most of the small olives, fruit damaged in pickling, frosted and other cull olives are utilized for oil (see Chapter XXVI).

Some of the small olives are pickled and pulped in a tomato pulper equipped with a heavy specially constructed screen. The resulting "puree" is mixed with salt and spices, and is then canned and sterilized. It is known as "olive mince" or "olive relish" and is used for sandwich fillings, sauces and as a flavoring in cooking. Chopped pimientoes, green peppers and horse-radish give an excellent blend with olives.

The pomace from olive oil manufacture is utilized in California for fuel, but in Europe is extracted with volatile solvents for recovery of the residual oil (see Chapter XXVI on olive oil).

UTILIZATION OF VEGETABLE WASTE

In the canning of vegetables and the manufacture of tomato products a considerable proportion of the vegetables is discarded as waste or is often only partially utilized. Studies by Rabak[3] and others have proved that waste tomato seeds and skins in particular are worthy of study for the preparation of by-products.

By-products from Tomato Seeds and Skins.—Rabak[5] estimates the average quantity of waste peels and seeds from tomato products factories at 16,000 tons on a wet basis or, approximately, 3,000 tons of dry material, of which about 1,500 tons are seeds and 1,500 tons dry skins.

Drying the Waste and Separating Seeds.—The seeds must be separated from the skins before the oil is extracted. In Italy, according to Rabak,[5] the waste is passed through a continuous press to remove as much of the excess water as possible and it is then dried in a continuous dryer by a blast of air heated by steam coils.

The seeds are separated from the dried material by screening and fanning.

Extraction of the Oil.—The oil is usually recovered by pressure in an expeller, *i.e.*, continuous oil press, or by solvent extraction. A maximum of about 20 per cent of oil is obtainable by this means. The press cake may be combined with the dry peels for stock food.

Refining the Oil.—The objectionable odor of the raw oil may be removed by treatment with a current of steam, the excess acid may be neutralized with sodium carbonate, or dilute sodium hydroxide and heating with fuller's earth and filtration will remove excess color. The refined oil is suitable for food.

Centralized Plants Necessary.—It is not feasible for individual canneries and tomato products factories to undertake the manufacture of tomato by-products. It would be possible, however, to dry the waste at the various plants and ship it to a centrally located plant to be converted into oil and stock food.

Asparagus Waste.—In the cutting of asparagus stalks for canning approximately 50 per cent is wasted. Some of the material is shredded or ground or cut in short segments and canned for soup stock, but most of the waste is discarded. It contains 93 to 97 per cent moisture and is of little value for stock food. It has been found that a palatable concentrated soup stock can be obtained by evaporating in vacuo a water extract of the boiled stalks.

Waste from Pea and Corn Canning.—The vines and pods from pea canning and the husks from corn canneries are seldom allowed to go to waste, but are used as stock food, either in the fresh state, or dried and cured as hay or fodder, or as ensilage. Pea vines are improved for siloing purposes, if mixed with corn silage, for the reason that they are apt

to undergo undesirable putrefactive changes in the silo, unless mixed with other materials low in protein and rich in carbohydrates.

Green corn cobs from canneries are rich in carbohydrates and may be used in the silo if finely shredded.

Spinach crowns and trimmings are succulent and low in food value, but can be utilized profitably for feeding purposes, if not allowed to become moldy or otherwise decomposed.

Vegetable Oils.—The manufacture of by-products from cottonseed, soy beans, peanuts, sesame seed and corn germs, etc., although extremely important, does not logically fall within the scope of this book, because they are field crop by-products rather than fruit or vegetable by-products. The subject of fixed vegetable oils is so important and the published literature is so extensive that a separate book would be required to do it justice.

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CHAPTER XXVIII

CITRUS BY-PRODUCTS

The utilization of the fruit unsuitable for fresh shipment has become a serious problem in the citrus fruit regions of the United States. However, rapid progress is being made in the development, on a commercial scale, of processes for converting this waste fruit into valuable by-products.

The manufacture of lemon by-products in Italy and Sicily is an established industry of long standing, but the methods in use in Italy are for the most part not adaptable to American conditions, because hand labor, upon which the Italian processes depend, is too costly here. The development in the United States has therefore been in the nature of devising mechanical means of accomplishing what is done in Italy by hand methods.

MANUFACTURE OF CITRIC ACID IN CALIFORNIA

Citric acid is used in very large quantities in the preparation of carbonated beverages and in the dyeing of fabrics. The United States, according to a report of the Citrus Protective League of California, imports about 75,000 pounds of citric acid and about 6,000,000 pounds of citrate of lime per year. The citrate is converted into citric acid in factories located in various cities on or near the Atlantic Coast. In addition a considerable quantity of citric acid is produced in California from cull lemons.

Raw Material.—Cull lemons from the fresh fruit packing houses form the usual raw material. Most of this fruit is sound and practically free from mold or decay.

The fruit is shipped to the factory often in open gondola cars holding 20 tons of fruit each. Smaller shipments are received by truck or in sacks or boxes by freight.

Sorting.—By the process in use until 1921 the fruit was first sorted on a broad conveyor. That free from rot and serious blemishes was sent to the peeling machines to be peeled for oil recovery before being crushed for citric acid manufacture. At present most of the fruit is not sorted before crushing and very little is peeled before crushing.

Peeling.—At one time much of the fruit was peeled or grated in mechanical peelers similar in appearance and operation to the mechanical peelers described in Chapter XXII for the peeling of potatoes and other vegetables.

The peels so obtained were pressed and distilled to recover the essential oil of the lemons. At present most of the fruit is pressed without peeling and the oil is recovered by other means than by pressing.

Extraction of the Juice.—The fruit first passes by means of an elevator to a slicer fitted with revolving knives which tear the fruit coarsely and facilitate pressing, and through wooden rollers which bruise the fruit thoroughly and press out some of the juice.

The crushed fruit is pressed in a continuous screw press which expels the juice mixed with considerable pulp. The pressed material is elevated to a soaking box where it is wet with water and is pressed a second time to recover the acid remaining in the press cake. The press cake from the second pressing is again soaked with water and pressed a third time. The third pressing juice is used for maceration of the pulp from the first pressing, while the second press juice is combined with that from the first pressing in the measuring tank. The combined liquids contain about 4 per cent of citric acid.

Experiments have been made upon extracting the juice by means of large fluted rolls without previously cutting the fruit. The rolls extract some of the oil which may be recovered by distillation and centrifuging.

Fermentation of the Juice.—The freshly pressed juice is very difficult to filter on account of the presence of gums and pectin, but it has been found that fermentation of the juice destroys much of the "sliminess" and renders filtration rapid. The juice is stored in large tanks holding about 57,000 liters each and is permitted to undergo spontaneous alcoholic fermentation. Fermentation requires about 5 days in warm weather and about 10 days in cold weather. Very little citric acid is lost during fermentation. Prolonged standing of the juice results in the growth of *Mycoderma vini* ("wine flowers") with resulting rapid loss in acid. The juice must be handled promptly after fermentation is complete.

Boiling.—The fermented juice is mixed with 1¼ to 2 per cent of infusorial earth in wooden tanks heated by copper steam coils. During boiling of the mixture, samples are withdrawn and allowed to settle a few minutes. If settling is not rapid, more of the earth is added until the desired result is obtained.

Filtration.—The hot liquor is filtered by means of a copper-lined Sweetland filter press and by plate and frame filter presses of large size and capacity.

The filtrate from the filter press is brilliantly clear, is of light amber color and contains about 4 per cent of citric acid.

Precipitation of Calcium Citrate.—The filtered juice is placed in wooden tanks fitted with steam coils and mechanical agitators. Based on a titration of the total acid of the juice enough hydrated lime is added to neutralize approximately 90 per cent of the total acidity of the juice estimated as citric acid. The remaining 10 per cent of the acid is neu-

tralized with calcium carbonate and an excess of carbonate is added. If hydrated lime is used to neutralize the acidity completely it darkens the color, renders decolorization of the liquids later in the process very difficult and causes the final crystals to be dark colored.

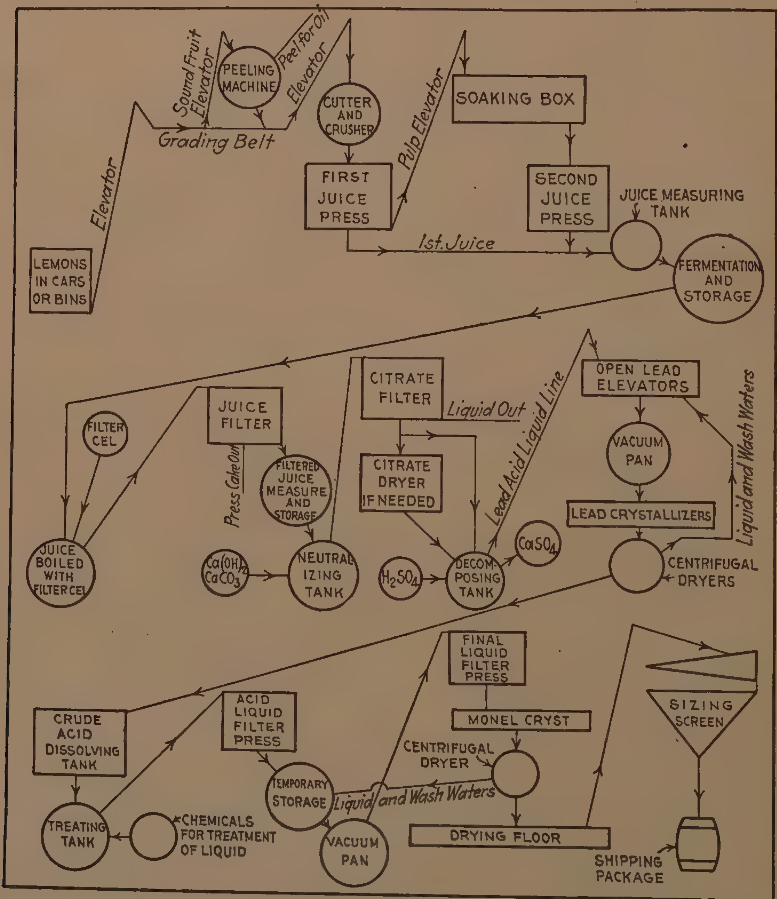

FIG. 98.—Flow sheet for the manufacture of citric acid. (*After C. P. Wilson, Exchange By-Products Co., Research Laboratory*).

The mixture is agitated and boiled until the reaction is complete. The boiling hot solution is pumped to the filters.

Filtration to Recover Calcium Citrate.—Neutralization of the juice with calcium hydroxide and carbonate results in the formation of insoluble calcium citrate, which is obtained as a finely divided white precipitate. Calcium citrate is more insoluble at high than at low temperatures and it is therefore necessary to filter the liquor at as high a temperature as possible.

Rotary continuous suction filters are used in filtering the citrate liquors to recover the citrate. The solid calcium citrate accumulates on the surface of the revolving drum and is scraped from the drum into a conveyor.

The wet calcium citrate is conveyed to the tanks for decomposition with sulphuric acid, although at one time some of the citrate was dried and shipped to eastern factories for manufacture into citric acid. Dry citrate should contain about 67 to 68 per cent citric acid; *i.e.*, if the citrate is decomposed with a mineral acid, 67 to 68 per cent by weight of citric acid should be liberated.

Decomposition of the Citrate.—The filter cake is mixed with wash water from a previous lot of calcium sulphate crystals to form a thin paste. Sulphuric acid (66° Baumé) is mixed with the citrate and the mixture agitated until the reaction is complete. If the acidity and the volume of the original juice are known it is possible to calculate the approximate amount of sulphuric acid required for liberation of the citric acid. It is desired that there be present after the reaction is complete not more than 0.2 per cent of free sulphuric acid.

The end point is determined by testing the liquor with methyl violet indicator paper, the end point being indicated by change of the violet color to greenish-blue.

A slight excess of sulphuric acid aids in crystallization of the acid, but a large excess will cause darkening of the acid liquors by caramelization and will cause the finished citric acid crystals to be dark in color.

Filtration to Remove Gypsum.—In the decomposing tanks calcium sulphate (gypsum) is formed as an insoluble precipitate and the citric acid goes into solution. The acid liquor has a density of 5 to 6° Baumé and an acid content of 12 to 15 per cent citric acid.

The calcium sulphate precipitate is removed by means of a continuous suction filter and may be dried and used by the orchardists as a fertilizer.

The filtered liquor is brilliantly clear and of light amber color.

Concentration of Acid Liquor.—The filtered acid liquid is placed in shallow lead-lined tanks heated by coils to near the boiling point. Air is passed through the liquid continuously and causes fairly rapid evaporation of the excess water, until the liquid is concentrated to about 25° Baumé. The calcium precipitate which forms is filtered off. Concentration of the first liquor is completed in lead-lined vacuum pans holding about 7,000 liters each; the final density of the hot liquid (at 50°C.) is 37 to 39° Baumé.

First Crop of Crystals.—The concentrated solution from the vacuum pan is placed in lead-lined crystallizing vats and allowed to stand from 3 to 5 days, permitting the formation of large crystals of citric acid on the walls and floor of the vats.

Centrifuging.—The crystals are placed in a centrifuge basket and washed with sprays of cold water to remove adhering mother liquor. The mother liquor is of dark color but yields a second crop of crystals by

concentration and crystallizing. When the mother liquor no longer yields desirable crystals it is sent to the neutralizing tanks, is diluted with water and treated as fresh juice so that none of the acid will be discarded.

Dissolving Crude Crystals and Removal of Metallic Salts.—The centrifuged crystals are dissolved in water by placing the crystals in a lead basket at the surface of a tank of water.

The impurities to be removed are: (1) organic color, (2) lead salts, (3) copper, tin and antimony salts, (4) iron and nickel salts, (5) sulphuric acid and (6) calcium sulphate.

The organic coloring matter is removed by heating the liquor with 1 to 2 per cent of its weight of high-quality decolorizing carbon. The liquid is filter pressed to remove the decolorizing carbon.

Sulphuric acid, if present in excess, is precipitated by adding to the liquor in the vacuum pan a calculated amount of milk of lime (hydrated lime) and the precipitate removed by filtration before decolorization with carbon.

Hydrogen sulphide water is added to the liquor to precipitate lead, copper, tin and antimony salts, which may have been dissolved by the acid solutions during their passage through pipes, by heating in lead tanks or by contact with metal at other points in the process.

When iron first dissolves in the juice it is in the ferrous state. Treatment with air in the open evaporators oxidizes it to the ferric state, making it possible to precipitate it as a ferrocyanide. The amount of calcium ferrocyanide found necessary by laboratory test to precipitate the iron and nickel salts is added to the acid solution. If left in the solution, iron and nickel salts would discolor the final acid crystals and render them unsalable as U. S. Pharmacopeia citric acid.

Enough ferrocyanide is added to precipitate about 90 to 95 per cent of the iron and nickel salts. An excess of the ferrocyanide would pass into the monel metal vacuum pan and there react with the nickel to give nickel ferrocyanide, which would discolor the final crystals. The small traces of iron and nickel left in the liquor do not affect the color of the citric acid crystals.

These reagents are added before the filter char is added. This is next added as noted elsewhere and the mixture is filtered through a cloth and frame filter press.

Concentration in Vacuo.—The filtered acid solution is concentrated in a glass-lined vacuum pan to 36 to 37° Baumé (at 50°C.).

Filtration to Remove Calcium Sulphate.—The concentrated liquor is again filter pressed to remove calcium sulphate precipitated during concentration and small amounts of other insoluble metallic salts that may be present.

Final Crystallization.—The filtered, concentrated liquor is placed in glass-lined or monel-metal-lined vats for final crystallization. During

crystallization the crystals are stirred occasionally by paddles by hand or continuously by mechanical stirrers, to prevent the formation of large crystals. Crystallization generally requires 3 to 5 days.

Centrifuging the Final Crystals.—The crystals are washed in a basket centrifugal with a small amount of water and the washings recovered and mixed with other acid liquors.

Drying the Crystals.—The crystals are usually dried in the open air on the floor in a layer about 4 to 5 inches in depth, but in rainy weather it is necessary to dry them by artificial heat in a vacuum-shelf type of dryer.

The crystals are packed in paper-lined barrels or boxes and in order to conform to the U. S. Pharmacopeia standards in purity must contain less than 0.5 per cent ash and be water-white in color.

CALCIUM CITRATE AND LEMON OIL MANUFACTURE IN ITALY

Very little citric acid is made in Italy, although a large amount of the intermediate product, calcium citrate (usually known in the trade as citrate of lime), is produced and exported to Germany, England and the United States to be converted into citric acid. Oil of lemon is also produced on a large scale for export. Other Italian lemon by-products are salted peel and concentrated lemon juice.

The preparation of oil and citrate is conducted under one roof and from the same fruit—hence the necessity of considering the two processes together.

According to Powell,[3] Italy normally exports approximately 17,000,000 pounds of citrate of lime. He also states that the normal amount of lemon oil exported from Italy is approximately 1,000,000 pounds annually.

Extracting the Oil.—The oil is usually extracted by hand, two methods of preparing the rind being used. In the "three-piece" method the rind is removed in three strips lengthwise of the lemon. In the two-piece method the lemon is cut in half and the flesh is scooped from the fruit by means of a sharp spoon. The pulp from either method of peeling is used for the preparation of juice for citrate and the rind is used for oil.

The peels are pressed by hand over a bowl; the juice and oil are caught by sponges and are periodically pressed into the bowl. The oil is decanted from the juice by tilting the bowl forward and blowing the breath on the surface of the oil.

The oil is allowed to settle for 24 hours and is then filtered through paper and stored in large copper cans, which exclude light and thus minimize deterioration.

The residue from the bowl contains considerable oil, which is recovered by distillation in crude stills. Distilled oil is of poor quality and becomes "terpeney" (of turpentine-like odor) rapidly but is often used in adulterating the hand pressed oil.

Chace[3] states that in Calabria, lemon oil and oil from the rinds of oranges are obtained by use of a machine in which the whole fruit is placed between two discs which have rough, abrasive surfaces and one of which revolves. The outer portion of the rind is grated from the fruit, the grated fruit wiped with a sponge and the juice and oil so collected expressed from the sponge. The oil is of excellent flavor, is darker in color than the hand pressed oil and is used largely for blending with the latter to intensify its color.

Citrate of Lime.—The pulp or peeled fruit from the oil room is crushed by wooden rollers operated either by mechanical means or by hand power. The crushed fruit is placed in heavy, closely woven, straw mats and these are placed one above the other and subjected to heavy pressure in a large screw hand press, the bags acting as filters as well as press cloths.

The juice is placed in a tank in which it is heated nearly to boiling by a steam coil or by direct heat, and milk of lime is added until the liquid is neutral to litmus paper. After heating for several hours the hot liquid is placed in a tank fitted with a filtering cloth on which the citrate collects as a voluminous white powder. After the liquor has drained off the citrate is shoveled into small bags and pressed to remove excess liquid.

It is removed from the bags to iron pans, which are stacked on racks in a room heated with a large charcoal burner, and there dried.

The dry citrate is broken into small pieces and packed in hogsheads holding about 675 pounds each. Each lot is sampled, analyzed and is sold to brokerage houses. The citrate usually contains more than 60 per cent of citric acid.

Citric Acid.—The citrate is converted into citric acid in Germany, England and the United States by methods similar to those described earlier in this chapter.

Yields.—Chace[3] states that 100,000 lemons (10 to 12 tons) yield 100 pounds of oil and 675 pounds of citrate of lime. This corresponds to 8½ to 10 pounds of oil and about 56 to 67 pounds of citrate per ton, or approximately 35 to 43 pounds of citric acid per ton.

ORANGE AND LEMON OILS IN CALIFORNIA

Four methods have been used in California for the recovery of the essential oils from cull oranges and lemons. These processes are: (1) by pressure and centrifugal separation, (2) by steam distillation, (3) by removing the outer portions of the rinds by grating and pressing of the resulting grated rind and (4) by extraction with petroleum ether.

By Pressure and Centrifugal Separation.—The whole fruit is crushed and pressed in a continuous pressing device, the oil and juice separated by means of an ordinary cream separator and the crude oil filtered through paper. The yield is relatively low, seldom in excess of 6 pounds per ton.

The oil is usually lower in citral content than the imported oil because the juice dissolves an appreciable proportion of this ingredient.

Waste orange juice is used for vinegar manufacture or preparation of syrup for soda fountain and bottler's use. The lemon juice is used for citric acid manufacture.

By Steam Distillation.—The gratings from mechanically peeled oranges or lemons or the pressed whole fruit may be ground and distilled in a current of steam to recover oil not removed by other means. The resulting oil is water-white and much inferior to the cold-pressed oil in color and flavor. It is also very unstable and rapidly deteriorates unless held in cold storage.

Steam distillation in vacuo yields an oil superior in flavor and keeping quality to that obtained by steam distillation at atmospheric pressure.

By Peeling and Pressing.—Lemons and oranges may be peeled in a modified vegetable peeling machine, which removes the outer portion of the rinds in the form of gratings which may be pressed to obtain an oil of good quality. The press cake may be distilled in a current of steam to recover the remainder of the oil, which will be of poor flavor and poor keeping quality and should not be mixed with the cold-pressed oil.

Recovery of Oil by Use of Solvents.—At one time orange and lemon oils were prepared in Redlands, Cal., by the following method. The outer portion of the peels was first removed by hand peeling and the oil recovered by treatment of the peels with a volatile solvent. It was found impossible to remove the solvent completely from the oil and the process was therefore abandoned.

OTHER CITRUS BY-PRODUCTS

Numerous other citrus products and by-products are produced commercially in the United States and in European countries.

Marmalade.—England imports from Spain large quantities of oranges, which are utilized in the preparation of marmalade and in California and Florida marmalade is produced commercially from cull citrus fruits (see Chapter XVII).

Marmalade Juice.—It has been demonstrated by experiments at the University of California that the juice expressed from cooked citrus fruits and combined with the sliced peels can be sterilized in cans and shipped to marmalade factories or sold to housewives for the preparation of marmalade. It is believed that this product has commercial possibilities (see Chapter XVII).

Citrus Fruit Juices and Syrups.—Large quantities of cull oranges are used for the preparation of juice which is sold direct to the consumer immediately after it is produced. Appreciable quantities of citrus fruits are also used for the preparation of syrups (see Chapters XV and XVI).

Orange Vinegar.—Orange juice normally contains from 12 to 16 per cent total solids, of which about 9 to 13 per cent is sugar. If the juice is carefully fermented with selected yeast, it is possible to obtain a fermented juice containing 4.5 to 6 per cent alcohol by volume, which will yield vinegar above the legal limit of 4 per cent acetic acid (see Chapter XXIV).

Dehydrated Citrus Products.—Orange and lemon peels are dried in halves to a limited extent for the use of extract manufacturers and bakers and for use in flavoring medicinal preparations.

Recently the sliced fruit has been dehydrated until very brittle and has then been ground to a powder. The powder is used as a flavoring material in cakes, pies, cookies, etc., and for flavoring plug tobacco.

Dried Juices.—Lemon and orange juices may be dried to powders in the same manner as milk, egg white, etc. (see Chapter XVI).

Pectin.—Lemon waste from the manufacture of citric acid is very rich in pectin. C. P. Wilson[5] and his associates in the Research Laboratory of the California Fruit Growers' Exchange have developed a process of preparing a powdered lemon pectin commercially (see Chapter XVII).

Candied Peel.—Candied citron (a citrus product) is a well-known article of commerce. The citron peels are shipped in brine to the United States from Italy and the tropics for preparation of candied peel. The bitterness is extracted by boiling in repeated changes of water and the peel is candied by methods described in Chapter XVIII.

Orange and lemon peels are also imported from Italy in brine and converted into candied peel.

Paste for Bakers' and Confectioners' Use.—In California a paste is prepared from oranges by grinding the whole fruit, adding sugar and concentrating in a glass-lined vacuum pan to a heavy consistency, giving an excellent product for flavoring cakes, pies and other bakery products and for use in candies. Another product for baker's use consists of the ground whole fruit and an equal weight of sugar sterilized in cans.

Confections.—In addition to the candied peel it is possible to prepare candy from citrus fruits, a very satisfactory candy center being made by combining lemon pectin and ground, whole, cooked orange pulp with sugar and concentrating to the jelling point. The stiffly jelled mixture can be molded in starch or cut in cubes and dipped in chocolate or coated with fondant.

Canned Citrus Fruits.—Grapefruit pulp is now canned in Porto Rico and Florida to be served as a breakfast dish (see Chapter XI). Cubed grapefruit blends well with other fruits in canned fruit cocktails, salads, etc.

Oranges were at one time canned in California after peeling by hand and slicing crosswise in thin sections. These were canned in a syrup of about 40° Balling and were pasteurized in the can. The canned prod-

uct was used by sailing vessels, but a disagreeable "stale" flavor developed in the can on storage.

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CHAPTER XXIX

PACKING CASES*

In recent years a great deal of study has been given by governmental and commercial agencies to the design, construction and behavior of all types of containers for canned and glassed foods for the purpose of improving the containers and of conserving timber. Both objects have been attained to a remarkable degree. In many cases investigations have resulted in a saving of 30 to 40 per cent in lumber and shipping space and at the same time in producing a more serviceable packing case.

The most extensive work on box design and testing has been done in the Forestry Products Laboratories of the Forest Service, U. S. Department of Agriculture at Madison on the campus of the University of Wisconsin. At the Mellon Institute in Pittsburgh investigations upon packing cases have been made and a well-equipped box-testing laboratory has been maintained. Several box manufacturers and box manufacturers' associations have also conducted box-testing investigations. Among these may be mentioned the research department of the Chicago Mill and Lumber Company.

Extent of the Industry.—Of the total annual cut of lumber of approximately 40,000,000,000 board feet, about 6,000,000,000 board feet are used for boxes and crates. Although box lumber is often a by-product and therefore often less expensive than the longer and more perfect pieces, a conservative estimate of the value of box lumber would be $20 per 1,000 board feet, corresponding to about $120,000,000 per year for the lumber used for boxes. This is in addition to the fiber board and corrugated fiber cases made from paper waste and wood pulp.

Types of Packing Cases.—Three classes of cases are generally used for food products. These are nailed wooden boxes, wire-bound wooden boxes and fiber board (including corrugated fiber board) boxes. The cut pieces used in box construction are known collectively as "box shook."

NAILED WOODEN BOXES

The nailed wooden box is still the most important packing case for fruit and vegetable products, although the popularity of wire-bound boxes and fiber boxes is rapidly increasing.

* Most of the material in this chapter was obtained from Professor E. Fritz of the Forestry Division of the University of California and from articles published by Don L. Quinn in the *Canning Age*, 1922 and 1923. Grateful acknowledgment is made for the information so obtained.

Requirements of a Box.—A box must protect its contents against damage and tampering; it must be serviceable and yet economical; it should be attractive in appearance and permit of printing or labeling, since the packing case is one of the best mediums of advertising.

Causes of Failure of Boxes.—The weakest point in the construction of any box determines its serviceability. The box should be so constructed that all parts are of as nearly equal strength as it is possible to make them.

Frequent causes of failure of boxes are: (1) the use of too few nails; (2) the use of too large nails; (3) the use of too small nails; (4) driving the nails too near the edge of the boards; (5) overdriving the nails; (6) use of ends too thin to hold the nails; (7) ends of boxes not properly reinforced; (8) use of too thin pieces for sides, top or bottom; (9) use of wrong species of wood; (10) use of too many pieces; and (11) use of unseasoned lumber.

General Specifications for Nailed and Lock-corner Wooden Boxes.—The Forestry Products Laboratory, the canners, wholesale grocers and box manufacturers in conference with the Consolidated Classification Committee of the transportation companies in September, 1921, adopted definite specifications for nailed and lock-corner boxes. These specifications, although not final, represent a very important advance in the standardization and improvement of box construction. The specifications may be obtained from the Forestry Products Laboratory, Madison, Wis. A few of the more important sections of the specifications are given herewith.

Material.—Under average conditions, thoroughly seasoned lumber has a moisture content of 12 to 18 per cent, based on the weight of the wood after oven drying to a constant weight.

Grouping of Woods.—The principal woods used for boxes are classed for the purpose of specifications in four groups:

Group I

White pine	Willow
Norway pine	Noble fir
Aspen (Popple)	Magnolia
Spruce	Buckeye
Western (Yellow) pine	White fir
Cottonwood	Cedar
Yellow poplar	Redwood
Balsam fir	Butternut
Chestnut	Cucumber
Sugar pine	Alpine fir
Cypress	Lodgepole pine
Basswood	Jack pine

Group II

Southern yellow pine	Douglas fir
Hemlock	Larch (Tamarack)
North Carolina pine	

Group III

White elm	Black ash
Red gum	Black gum
Sycamore	Tupelo
Pumpkin ash	Maple, soft or silver

Group IV

Hard maple	Birch
Beech	Rock elm
Oak	White ash
Hackberry	Hickory

Thicknesses of Lumber.—The thicknesses called for in specifications for boxes of any given commodity will, unless otherwise stated, be understood as applying to Groups I and II woods. Where the material is specified (for Groups I and II woods) as not more than ½ inch thick and not less than ¼ inch, Groups III and IV woods may be used ⅟16 inch less in thickness; where the material is specified (for Groups I and II woods) as more than ½ inch thick and not more than 1 inch, Groups III and IV woods may be used ⅛ inch less in thickness; where the material is specified (for Groups I and II woods) as more than 1 inch thick and not more than 2 inches, Groups II and IV woods may be used ¼ inch less in thickness.

Width of Material.—The maximum number of pieces allowed in any side, top, bottom or end of a box shall be as follows:

Width of Face	Maximum Number
4 inches and under	1
4 to 7 inches, inclusive	2
7 to 10 inches, inclusive	3
Over 10 inches to average not less than 3 inches wide and no piece to be less than 1½ inches wide at either end if matched, not less than 2 inches wide if butt jointed.	

Surfacing.—The outside surfaces of boxes must be sufficiently smooth to permit of legible marking.

Suitability of Various Woods.—For dried fruits and other fruit products not sealed in airtight containers the box must be made of wood that will not impart a foreign odor or flavor to the product.

In general, wood for boxes should be light, tough, of good nail-holding power, resistant to splitting, low in resin, free from objectionable odors, soft and easily worked and should possess an attractive surface that will permit printing and will take label paste. In addition, the price must not be excessive. Some woods are suitable for heavy crates but split badly or exhibit other undesirable qualities when used for boxes.

The Western Yellow pine, often known to the lumberman as "White" pine, is one of the most important box lumber woods in the United States.

About 1,500,000,000 board feet of this lumber are cut in California per year foı boxes, much of it by mills owned by the fruit growers' and packers' organizations of California. The Western Yellow pine is available from South Dakota and Texas West.

The Eastern White pine is used extensively in New England and the Lake states and the Southern Yellow pine is a very important box lumber tree of the southern United States.

In the Pacific Northwest the Sitka spruce is used very generally for boxes, the box lumber usually being a by-product from mills producing lumber for other purposes.

"Oregon pine" or Douglas fir is too heavy and splits too easily to render its use for boxes advisable. It is, however, one of the most important trees now cut for lumber for general purposes. Redwood, a very important Pacific Coast lumber tree, is not tough enough for boxes and splits easily.

The hardwoods, oak, ash, maple, birch, etc., are generally too costly for use in boxes. They are also very hard and are difficult to nail.

In general, it may be said that the pines are by far the most important source of box lumber and of these the Western Yellow, the Southern Yellow and Eastern White pine are the most widely used.

Revolving Drum Box Tester.—In the Forestry Products Laboratory at Madison, Wis., a large revolving drum is used to imitate the shocks and handling met by boxes in transit. This drum is shown in Fig. 99.

It is of hexagonal form, each face of the hexagon being 7 by 8 feet. The drum is 14 feet in diameter across the corners, weighs approximately 27 tons and will test boxes up to 4 feet in each dimension and weighing 1,000 pounds or less.

The drum rotates at the rate of one revolution per minute. Each inner face of the hexagon is fitted with a projection which carries the box to a definite height before it drops to the floor of the revolving drum (see Fig. 99).

The drum tester is used in determining the effect of various methods of nailing boxes, of reinforcing the ends or sides, the suitability of various woods and other factors.

Since the different boxes are subjected to the same treatment in the drum, it has been possible from the number of falls which are required to cause failure, to determine the relative strength of the boxes in terms of per cent. From the drum test, drop test and other laboratory data engineers of the Forestry Products Laboratories have been enabled to design boxes for many products that are lighter, require less wood and are stronger and cheaper than boxes formerly in use.

The Drop Test.—This test is frequently used to compare the strength of different species of woods used in box construction. The box to be tested is elevated to a definite height above a heavy cast-iron plate and

is dropped repeatedly until failure occurs. The boxes are dropped from different positions so that the resistance to impact applied to ends, sides, top, bottom and corners is determined.

Compression Test.—Boxes often fail because of the pressure of other boxes piled above them or because of other stresses and strains occurring

FIG. 99.—Failure of canned goods box in box-testing drum. (*Forest Products Laboratory, Madison, Wis.*)

during loading of cars and holds of ships and during shipment by rail, truck or boat. In order to simulate these strains, pressure is applied to empty boxes in a press similar to a fruit juice press in appearance. The floor of the press is the platform of a scales and the pressure upon this platform is recorded by a beam and weights. Pressure is applied until the box fails and the pressure at the time of failure is recorded.

In some tests pressure is applied endwise, in others cornerwise and in others to the sides or top of the box. Its behavoir under different types of strains can thus be studied.

Nail-holding Power of Various Woods.—The Forestry Products Laboratory has made a careful study of the nail-holding power of various

woods and the principal conclusion drawn is that the nail-holding power is proportional to the density of the wood. Density is a function of the percentage of wood substance, exclusive of resin and water possessed by the wood. The results of the above-mentioned investigations are shown graphically in Fig. 100.

Effect of Moisture Content and Storage on Box Strength.—The Forestry Products Laboratory at Madison has found that the moisture

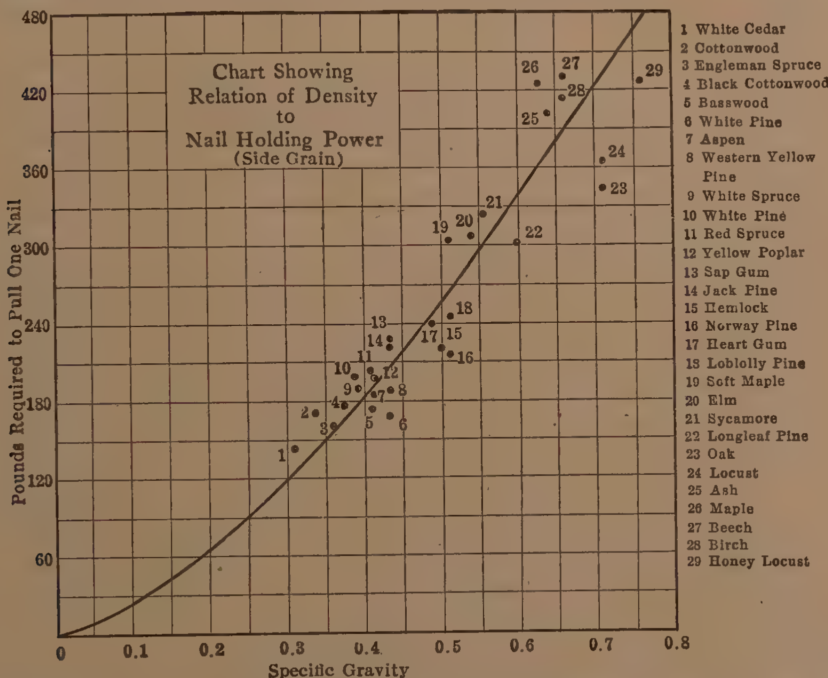

FIG. 100.—Relation of nail-holding power to density of various woods. (*After Forest Products Laboratory, Madison, Wis.*)

content of wood at the time of nailing affects the strength of boxes to a surprising degree. Boxes made from green lumber were found to suffer marked decrease in strength after 1 week's storage. If green or wet lumber is used it dries after the box is made and the wood shrinks away from the nail, thus enlarging the hole and weakening the nail-holding power of the wood.

The best results were obtained by use of lumber thoroughly seasoned under conditions to which the boxes were to be subjected in storage. Thoroughly air-dry lumber of 12 to 15 per cent moisture gave good service.

Nails.—Nails must be driven closely enough together to give the desired structural strength to the box and yet not cause splitting. The number of nails used greatly affects the strength of the box. The Forestry Products Laboratory found in one box making test that five

nails gave 50 per cent greater strength than four nails, and six nails 100 per cent greater strength than four nails. Use of a sufficient number of nails increases the strength of the box and permits the use of lighter pieces.

Cement-coated nails were found to have from 10 to 30 per cent greater holding power than plain nails and long, slender nails were found superior in holding power to short or thick nails.

The general rule suggested by the Forestry Products Laboratory for the sizes of nails for different woods is as follows:

> For woods of medium hardness, the "penny" of the nail must not be greater than the thickness, in eighths of an inch, of the wood which holds the point of the nail. In the case of softer woods, nails may be one "penny" larger and sometimes even two "pennies" larger. With hard woods, nails should be one "penny" smaller than called for by woods of medium softness.

The head of the nail should be broad and heavy to prevent its being pulled through the wood.

Nails driven into the side grain of the wood possess a greater holding power than when driven into the end grain. On this account nails should be driven closer together in the latter case.

Nails should be driven squarely into the center of the end of the box to give maximum holding power, to prevent splitting and to prevent them from coming out of the wood.

Overdriving greatly reduces the holding power of nails. They should be driven flush but should not be given an "extra tap."

The Forestry Products Laboratory has also found that nails driven at an angle of about 15 degrees hold very much better and give stronger boxes than nails driven vertically.

Spacing of Nails.—The spacing of nails is of great importance. A rule suggested for the spacing of nails in boxes is the following:

> For "six-penny" or smaller nails held in the side grain, there should be a spacing of 2 inches and for the same nail in the end grain a spacing of 1¾ inches. For larger nails the spacing should increase ¼ inch for each additional "penny" of the nail used.

This spacing is closer than that given by the average box-nailing machine, but is necessary in order to balance the strength of the box properly.

Nailing Schedule.—The National Association of Box Manufacturers has approved the sizes of nails given in the following schedule. Cement-coated nails are specified.

The Forestry Products Laboratory has recently approved a modified nailing rule which is as follows:

> When the thickness of the sides, tops and bottoms used is less than three-fourths the thickness of the parts determining the size of nail to use, then the nails may be one penny smaller than specified in the schedule. When the thickness of the sides, tops and bottoms used is the same as the parts determining the size nail to use, then the nail may be one penny larger than specified in the schedule.

TABLE 78.—NAILING SCHEDULE FOR BOXES

Group of wood	Thickness of ends or cleats in inches							Thickness of sides to which top and bottom are nailed		
	7/16	1/2	9/16	5/8	3/4	13/16	7/8	1/2	9/16	5/8–7/8
I	5d	5d	6d	7d	8d	8d	9d	4d	5d	7d
II	4d	5d	5d	6d	7d	7d	8d	4d	5d	6d
III	4d	4d	5d	5d	6d	7d	7d	3d	4d	5d
IV	3d	4d	4d	4d	5d	6d	7d	3d	4d	5d

WIRE-BOUND BOXES

Wire-bound boxes are made of relatively thin pieces of lumber held together by wires which pass completely around the boxes and give them greater strength than is possible by nailing. This box is elastic rather than rigid and offers greater resistance to shock than the nailed box. It has been adopted by several large food products manufacturers in preference to the nailed box or fiber board carton.

The Forestry Products Laboratory favors the use of this type of box because it uses less lumber than the nailed box and often that which is unfit for nailed boxes.

Advantages.—Quinn[1] has enumerated the advantages of the wire-bound box as follows:

1. Wire boxes weigh 25 to 50 per cent less than nailed boxes . . . The saving in space in export shipments amounts to about 5 per cent when wire-bound boxes are used.
2. Fewer losses from breakage result from use of wire-bound boxes.
3. The cost of making up wire-bound boxes does not exceed one-third the cost of making up nailed wood boxes.
4. Pilfering is greatly reduced by use of this type of box because it is impossible to open it in transit without such tampering being easily detected.
5. The packing of boxes for shipment is facilitated because the boxes are assembled at the point in the factory where they are to be used.
6. Wire-bound boxes will withstand great pressure, making it possible to stack the filled boxes to any desired height in the warehouse without fear of collapse.
7. The wire-bound box is adaptable and can be built to meet any requirements for canned goods and similar products.

A disadvantage of wire-bound boxes is their liability to puncture by other boxes or by contact with sharp projections of any sort. The thin pieces used in the sides, tops and bottoms are not very resistant to this hazard. However, boxes to be subjected to such hazard may be made of heavier material.

Comparative Strength of Wire-bound and Nailed Boxes.—A thorough study of wire-bound boxes has been made at the Rockaway Laboratory of the 4-One Box Machine Makers and the 4-One Association of Wire Bound Box Manufacturers, by A. K. Armstrong.

In one series of tests a wire-bound box built of Douglas fir was 500 per cent stronger than a nailed box of the same capacity built of Western Yellow pine. A wire-bound spruce box was 1,089 per cent stronger than the nailed box and approximately 100 per cent stronger than the wire-bound Douglas fir box. The material used in the wire-bound boxes was much lighter than that used in the nailed boxes.

Method of Making Wire-bound Boxes.—The wood used for the sides, tops and bottoms of wire-bound boxes is called "sheet material," and for domestic service is usually ⅛ inch in thickness.

The food manufacturer receives the wire-bound boxes with the sides, top and bottom in flat form joined together by stapled wire. This is known as the blank or mat and consists of four sections. The individual pieces are "sewed" or stapled in an automatic wiring and stapling machine at the box factory. The ends of the blank are attached to cleats by staples which are astride the wires and which pass through the side, top and bottom pieces into the cleats.

The ends consist of single pieces to be fitted to the ends of the blank after the latter is folded to form the bottom and sides of the box.

The filled box is sealed by folding the top into place and twisting the ends of the binding wires securely together by a small wire-tying machine.

Specifications.—Tentative specifications for wire-bound boxes for food products have been established by the 4-One Association of Box Manufacturers and the American Society for Testing Materials. Some of the more important points of these specifications are the following:

1. General Form. The boxes knocked down shall consist of four separate sections forming top, side, bottom and side, connected only by continuous steel binding wires; and of separate ends.

Each of the separate sections forming the sides, top and bottom shall consist of cleats, thin boards, wire and staples. The four sections shall be separated such a distance from each other that the wires shall be in tension when the sections are folded.

2. Woods are placed in four groups as for nailed boxes.

3. Cleats shall be not less than ¾ of an inch thick (parallel to the length of the box) and not less than ⅞ of an inch in width.

4. The thin boards shall be sound, free from decay, well seasoned and cut so that adjacent faces of boxes will be at right angles to each other. When the thickness of thin boards as specified is less than 3/16 of an inch, thin boards made of woods of Group III and IV may be 1/32 of an inch less than the specified thickness, except that the minimum thickness of thin boards of any kind of wood shall be ⅛ inch.

5. Thin boards less than 2½ inches in width at either end shall not be used.

6. Staples shall be of annealed wire of not less than No. 16 gage.

The staples on end wires shall be driven astride the binding wires, through the thin boards into the cleats and firmly anchored. The space between staples shall not exceed 2½ inches, except for woods of Group III and IV where the space between staples may be ¼ inch greater than the above distance.

FIBER BOXES

Quinn[1] states that more than $6,000,000,000 worth of various commodities are transported each year in fiber board containers. Fiber board boxes are light, convenient to use, attractive in appearance and effect a great saving in wood.

Fiber Board.—Fiber board used in the construction of boxes is of two general types, solid and corrugated. Solid fiber is built up of layers of heavy paper cemented together by silicate of soda. The outer layers are of "jute" board, *i.e.*, heavy tough paper, while the center is built up of lighter and weaker materials. The various sheets vary from 0.016 to 0.03 of an inch in thickness and the board made up of the individual pieces cemented together is of three standard thicknesses, 0.060, 0.080 and 0.100 of an inch, known as "60-point," "80-point" and "100-point" board.

Corrugated board differs from solid fiber board in that the interior is made up of a trusswork of relatively thin straw paper, which imparts a cushioning property to the board and makes it a desirable package for glass containers.

Using the Box.—The board is cut and folded at the factory and delivered in collapsed form to the canner or other user, who unfolds the box, seals or staples the bottom, fills the box and seals or staples it. Sodium silicate is the usual adhesive used in sealing bottoms and tops. It possesses great binding strength, is cheap and dries fairly rapidly. When dry it resists water and other liquids and gives a permanent union.

Fiber boxes are also frequently sealed with strips of adhesive tape.

Advantages of Fiber Boxes.—Fiber boxes use only about one-sixth as much wood as ordinary boxes and much of this represents waste board or paper used for the second time. The inner portion of corrugated fiber board is to a great extent made from paper pulp prepared from waste wheat straw. For these reasons fiber board conserves wood and thus tends to decrease the drain on the nation's forests.

Fiber boxes are cheaper than nailed or wire-bound boxes and the small operator requires no special nailing machine or other special equipment for sealing. The transportation charges for both the empty and the filled boxes are less than for other types of boxes and smaller storage space is required.

The assembling cost at the cannery or other food establishment is low. With a small inexpensive machine one man can seal 150 to 300 boxes per hour and with a large machine several thousand per hour.

Fiber boxes are much less liable than other boxes to cause injury to employees. Pilfering is much less common with fiber containers than with nailed boxes because of the difficulty of concealing tampering.

Corrugated board is a good shock absorber and on this account boxes made of this material are preferable to other boxes for glassed goods.

Fiber boxes take printing and lithographing very satisfactorily and provide a valuable advertising medium for food products.

Durability and Strength.—There is less variation in the strength of fiber boxes than nailed boxes, consequently the average strength of the former need not be as great. Nevertheless there is rather wide variation in the behavior of fiber boxes in shipment, because of improper sealing and improper stacking in the car. In overseas shipping tests made during the World War fiber board and corrugated fiber board boxes gave good service when not wet in transit.

Disadvantages.—They are not so rigid as nailed or wire-bound boxes and in general not so durable. Being made of wood pulp they are less resistant than nailed boxes to puncture.

The fiber box does not withstand storage well in the rain or in wet holds of vessels or in other positions where it may become water soaked, but progress is being made in developing water-resisting board.

Sealing Fiber Boxes.—Tests at the Mellon Institute show that effectiveness of sealing depends very largely upon securing good contact of the flaps with the top and bottom of the boxes. Where automatic machines are used, sealing is generally well done, but hand sealed boxes are frequently poorly sealed.

It was found that the boxes did not reach maximum strength at room temperature after sealing with sodium silicate in less than 4 hours, but when sealed and held at 120°F., maximum strength was attained in 5 minutes.

Pressure on the boxes after sealing and during drying of the silicate is desirable in order to give maximum strength to the box. Fiber board requires greater pressure than corrugated board because of the greater difficulty in "ironing out" uneven areas in the former.

Two types of tape, Kraft and Cambric, are used in sealing fiber boxes. The Cambric tape is much stronger and gives a more durable seal.

If the sides are improperly scored the flaps do not make good contact with the top and bottom, causing imperfect sealing and frequent failure of such boxes. The sides should be so scored that the underside of the flap does not crease on bending.

Stacking Fiber Boxes.—These boxes are difficult to stack and are liable to topple. If strips of wrapping paper are laid across the tops

of the stacked boxes between each tier of five boxes and if wooden strips are laid on the boxes near the edges of the stacks, the boxes stand well.

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CHAPTER XXX

THE VITAMINS IN RELATION TO FRUIT AND VEGETABLE PRODUCTS

In recent years no subject in the field of nutrition has aroused such widespread interest and discussion as that of the vitamins.

These imperfectly understood dietary essentials have been proved to be of fundamental importance in promoting growth and in maintaining health.

The effect on the vitamins, of pasteurization, sterilization, dehydration and various other processes used in the preparation of fruit and vegetable products has not been studied as thoroughly as some other phases of the vitamin problem; nevertheless, considerable valuable information has been accumulated on the effect of such processes on the vitamin content of some food products.

Historical.—It has long been recognized that the lack of fresh foods, particularly fruits and vegetables, often results in scurvy. English sailing boats at one time were compelled to carry lime juice to be used by the crew as a preventive of scurvy. It was known that crews affected with scurvy would recover quickly if given a diet rich in fresh fruits and vegetables. Kohmann[3] states that James Lind in 1757 called attention to the relation of scurvy to the lack of fresh vegetables in the diet.

According to Kohmann,[3] Smith[4] was one of the first to observe the effect of an exclusive diet of cereals on laboratory animals, reporting that guinea pigs died of a hemorrhagic disease when fed cereals alone without succulent vegetables.

Eijkmann[1] was probably the first investigator to prove that there is a definite relation between the disease known as "beriberi" and the character of the diet. He found that the symptoms of beriberi could be developed in fowls by feeding them on an exclusive diet of polished rice and water. On adding rice polishings, which contain the outer skins of the grains, the birds again became normal. This and later experiments by Eijkmann laid the foundation for the work of hundreds of other investigators on vitamins.

Investigators in the United States government service in the Philippines in 1898 to 1900 found that beriberi among the natives was apparently caused by an exclusive diet of polished rice.

Eijkmann reported further work in 1906, confirming his first investigations. From 1906 to 1911 a number of investigators were engaged in a study of beriberi and its relation to a rice diet and other factors. In

1911 Funk[5] obtained from rice polishings a crystalline substance which possessed to a very marked degree the property of curing polyneuritis (experimental beriberi) in fowls. He gave the name of "vitamin" to the substance, because his analysis showed it to contain nitrogen and gave evidence of being an amine. The name means, literally, "life amine." Later investigators proved Funk's crystals to be something other than the vitamin and that probably the vitamin was present in the crystalline substance as an impurity.

Following Smith's discovery that guinea pigs will not thrive on cereals alone, Holst and Frohlich in 1912 and 1913, Cohen and Mendel in 1918 and others found that experimentally produced scurvy in guinea pigs was due to a lack in the diet of an antiscorbutic vitamin.

McCollum and Davis, and Osborne and Mendel are to be credited with the discovery of a third vitamin in butter fat which has the power of curing experimental rickets and an eye disease, ophthalmia, in animals.

McCollum suggested the names of A, B and C for the three vitamins, A being antirachitic, B antineuritic and C antiscorbutic. These names have been used in the literature in preference to others that have been suggested.

General Properties.—At least three vitamins are now recognized, although there is some evidence that there may be more than three vitamins and that Vitamins A and B are not single substances.

Vitamin A is known as the "fat soluble vitamin," since it is much more soluble in fats than in water. Thus butter fat, one of the richest sources of Vitamin A, contains a much higher concentration of the enzyme than does skim milk. Egg yolk is very rich in vitamin A, which is also fairly abundant in vegetables, particularly the green leafy varieties. Tomatoes in any form (fresh, canned or dried), spinach, carrots, string beans, sweet potatoes, lettuce and green peas are known to be rich in Vitamin A. It is present in small amounts in most fruits. Most seeds contain appreciable amounts of this vitamin, but are not as good sources as the vegetables mentioned above.

The chemical composition of the vitamins is yet unsolved, only their general behavior and the physiological effects produced by them are definitely known.

Animals apparently cannot synthesize A or other vitamins—these must come from plants. Vitamin formation may be associated with chlorophyll activities in the plants. At one time it was thought Vitamin A and the yellow color of certain foods were closely allied, since yellow corn is richer in this substance than white corn. The present view, however, is that Vitamin A is a separate body.

Animals have the power of storing Vitamin A, particularly in the vital organs. Cod liver oil is the richest konwn source of Vitamin A, being 250 times as potent as butter fat.

Rickets is a common disease among infants nursed by mothers on a diet deficient in Vitamin A. Cod liver oil and butter fat have been found to be effective in curing rickets in children and in laboratory animals.

Lack of Vitamin A in the diet of rats results in failure to grow, hence the term "growth-promoting vitamin." However, lack of other food essentials also results in failure to grow. Continued lack of Vitamin A results in an inflamed condition of the eyes and malnutrition of the hairs, a condition termed ophthalmia, xerophthalmia, conjunctivitis or kerotomalacia.

Vitamin B, the antineuritic (or antiberiberi) vitamin, is water soluble. It is found in abundance in the bran layer and germs of cereals. The starchy portion of the grains is deficient in Vitamin B, a fact that explains the development of beriberi from an exclusive diet of polished rice or white bread.

Most vegetables, including leaves and roots, and tomatoes are very rich in Vitamin B.

If fowls (usually pigeons) are fed on polished rice, polyneuritis symptoms will develop with paralysis of the legs, neck and wings and death in a few days after the appearance of symptoms, unless food rich in Vitamin B is given. The cure is very rapid if the vitamin is supplied before the disease has progressed too far.

In the tropics where polished rice is the principal article of diet, infant mortality is very high from beriberi, caused by nursing on milk from mothers living on a diet of polished rice, deficient in Vitamin B.

Yeast is able to synthesize Vitamin B, according to McDonald and McCollum, and is particularly rich in this vitamin.

Although Funk and others have prepared extracts very rich in Vitamin B, there is no definite evidence that the pure vitamin has been isolated. Its chemical properties are, therefore, for the most part unknown. One means of concentrating Vitamin B is by treating liquids rich in this vitamin with fullers' earth, which has the power of absorbing it, the liquid from boiled yeast being a good source of the vitamin. Funk also concentrated the vitamin from an alcoholic extract of rice polishings by precipitation with phosphotungstic acid and was able to obtain a product free from proteins, carbohydrates and phosphorus and possessing marked antineuritic properties.

Vitamin B is sensitive to alkalies and is much more stable in acid than in alkaline media. Prolonged exposure to an alkaline medium destroys the potency of all of the vitamins.

Vitamin C, the antiscorbutic food accessory, is found in great abundance in citrus fruits and in their juices and in tomatoes (fresh or canned). Orange juice is the standard product for use in feeding laboratory animals in vitamin investigations. Raw cabbage is very rich in Vitamin C, but a large proportion of the vitamin is destroyed during

cooking. Sprouted cereals are rich in this vitamin; during sprouting, Vitamin B decreases and C increases. Whether B is converted to C during the germinating process is unknown.

In addition to the foods named above, raspberries and lettuce are known to contain Vitamin C in abundance. String beans, cooked cabbage, raw carrots, raw onions, white potatoes and peas contain fairly large amounts of Vitamin C. The common dried fruits, such as prunes, appear to contain only a small amount to none of Vitamin C. Apples, bananas, grape juice, lime juice and cooked carrots have small amounts of Vitamin C.

Guinea pigs are usually chosen for laboratory studies on this vitamin, because they are very sensitive to a lack of Vitamin C in the diet. The symptoms in the guinea pig caused by a lack of this vitamin are tenderness and pain in the knee joints, inflammation of the gums, loosening of the teeth and hemorrhages at the knee joints and ends of the ribs, according to Kohmann.[3] The disease can be cured by placing the animal on a diet rich in Vitamin C.

In man, scurvy symptoms do not always manifest themselves at once and according to Hess[9] there are many latent cases of scurvy in which the patient is subnormal in health but does not exhibit typical symptoms of scurvy. Probably this condition is rather widespread in early spring in regions where the winter diet does not include green vegetables or fresh fruits. Since canned tomatoes and fresh oranges have been proved to be very rich in Vitamin C, most of the population should find it possible to obtain an abundance of the antiscorbutic vitamin at all seasons of the year.

EFFECT OF HEAT ON VITAMINS

The three vitamins vary considerably in their resistance to heat, Vitamin C apparently being more sensitive in this respect than A or B. However, all three vitamins are affected adversely by heating.

Effect of Heat on Vitamin A.—Butter fat, according to Kohmann,[10] has been heated for 15 hours at 205°F., 6 hours at 212°F. and 4 hours under pressure in the absence of air without appreciable reduction in its Vitamin A content. Maize, chard, sweet potatoes, squash and alfalfa have been heated for 3 hours under 15 pounds pressure (250°F.) with no noticeable loss in Vitamin A. McCollum[3] reports that canned evaporated milk is rich in Vitamin A and commercially canned tomatoes are well known to be rich in Vitamin A. These facts indicate that this vitamin is very resistant to heating and that the temperatures used in the canning of foods do not materially reduce its potency.

It is, however, fairly sensitive to oxidation at elevated temperatures.

Effect of Heat on Vitamin B.—In reviewing the investigations of various men on the effect of heat on Vitamin B, Kohmann[3] states that

experiments show Vitamin B in yeast to be less resistant to heat than in vegetables. Thus heating yeast extracts to 252°F. for 1 hour destroyed from one-fourth to one-half of this vitamin and 2 hours' heating at 252°F. destroyed from one-half to three-fourths. Heating seeds to 250°F. for 1 hour had no appreciable effect on Vitamin B. Results of experiments on the effect of heat on Vitamin B in meat and eggs are less definite.

Vitamin B in milk has been found by various investigators to be fairly stable to heat.

Ordinary cooking temperatures according to Kohmann[3] do not noticeably reduce the Vitamin B content of vegetables. Canned carrots after 45 minutes' heating at 239°F. were apparently as rich in B as the fresh carrots.

Effect of Heat on Vitamin C.—Kohmann[10] has recently emphasized the relation between injury of Vitamin C by heat and by oxidation. Where oxidation is excluded by exhausting the food to remove air and where heating is conducted in the absence of oxygen, injury to Vitamin C is much less than where oxygen is present. It is usually very difficult to exclude oxygen from foods during canning, because of the presence of air dissolved in the food or in the surrounding liquid. The fact that lower temperatures (140 to 194°F.) produce practically as rapid destruction of Vitamin C in vegetables as higher temperatures (230 to 248°F.) indicates that some other factor in addition to heat may be active.

Cabbage in an experiment reported by Delf lost 70 per cent of Vitamin C after 1 hour at 140°F., 90 per cent after 1 hour at 194°F., 90 per cent after 1 hour at 212°F., 90 per cent after 1 hour at 248°F. and 93 per cent after 1 hour at 266°F.

In acid products, such as tomatoes, orange juice and fruits, Vitamin C is much more stable to heat than in products of relatively low acidity, such as cabbage and milk. Thus orange juice, according to Kohmann,[3] has withstood 1 hour at 212°F. and also 1 hour at 266°F., with loss of less than one-half of its Vitamin C content. Canned tomatoes are recognized as being very rich in Vitamin C.

RESISTANCE OF THE VITAMINS TO DRYING

Vitamin A and B are sensitive to oxidation; hence, it is to be expected that a decrease in these vitamins would occur during the drying of foods in air.

Vitamin A.—The Vitamin A content of dried milk is high, that of dried cabbage is very low and of dried tomatoes, spinach and carrots, high. Milk is dried at about 240°F., but the exposure to high temperatures is for a few seconds only.

Vitamin B.—Vitamin B has been found by various investigators to be fairly stable during the drying of foods. Kohmann[3] states that dried

yeast, dehydrated carrots, spinach, turnips, turnip tops, beets, tomatoes, potatoes and cabbage possessed marked antineuritic properties in experiments reported by Osborne and Mendel. Work on the effect on Vitamin B of drying of fruits has not been extensive, but it is to be expected that they would behave similarly to vegetables in this respect, *i.e.*, that Vitamin B should not be materially altered by drying.

Vitamin C.—Vitamin C is very sensitive to oxidation at the temperatures used in drying. However, experiments by Givens and others with powdered fruit juices prepared by the milk powder process show them to possess marked antiscorbutic properties. This is particularly true of orange juice. Apples and bananas in experiments by Givens and others were found to lose most of their Vitamin C in drying. Echman found that dehydrated apples, apricots, pears, prunes, cherries and loganberries possessed practically no antiscorbutic power. Dehydrated peaches delayed but did not prevent scurvy in guinea pigs.

It is to be expected, therefore, that most dried fruits will possess considerably less of Vitamin C than the fresh fruits.

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Note.—For further references on vitamins the reader is referred to the bibliographies in the Appendices of references 3, 6 and 9 of the above list.

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